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FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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Mining and Metallurgical Section.

Special Meeting, November 23, 1898.

SPECIFICATIONS ON STRUCTURAL STEEL AND RAILS.

DISCUSSION.

MR. W. R. WEBSTER:—The specifications for American structural steel and rails are on the whole very satisfactory. Some, of course, are behind the times, but common practice of to-day gives a much better material than they call for. On the other hand there are specifications in which the physical and chemical requirements do not agree, or that call for an extremely high elastic limit or other results, which cannot be obtained by the ordinary methods of manufacture and testing. Specifications of this kind cause the manufacturers temporary trouble, but soon adjust themselves, either by the engineer coming out frankly and modifying them, or giving instructions modifying the point at issue, though still adhering to his printed specification. The latter method is much to be regretted, as the specifications are very misleading, and the steel accepted under these modifications never has and never will meet the original requirements.

Our Government specifications, at first, gave the manufacturers considerable trouble, but when they found that the requirements of these specifications had to be lived up to in every particular, they were forced to improve their methods in each department, and, as a result, there has been a gradual improvement in the quality and finish of structural steel, due to more uniform methods of manufacture; the most important being the control of the finishing temperature, as more steel was formerly spoiled by being finished at too high temperature than in any other way.

The quality of steel depends (1) on its chemical composition; (2) on the treatment it receives in the course of manufacture; and we are learning year by year better to distinguish the results due to each. To-day, at some of the mills, they are getting results that were formerly considered impossible. I refer to rolling the steel into finished product, which meets all the requirements of the most rigid specifications, without stopping to make any preliminary tension test whatever. The steel is not allowed to cool from the original casting temperature until it is rolled into the finished product. This, of course, is a great saving of fuel, and increases the output. This great advance has been brought about by close observation of the methods of manufacture and the establishment of the relations between the chemical composition and the physical properties. The analysis of each heat is made while the ingots are still in the soaking-pit. The ultimate strength is estimated from its chemical composition, then the heat of steel is rolled on orders where it will apply, due allowance, of course, being made for the thickness of the finished product.

I have made a special point of the heat treatment of steel in connection with work, as the quality of the finished product depends more on it than is generally admitted or understood, and I consider that it is now the most promising field of experiment and research. To-day we hear less of the mysterious failures of steel than ever before, as, when a failure occurs in the shop or elsewhere, examination shows that in nearly all cases the trouble has been caused by improper treatment, and indicates the necessary improvements required in shop methods to avoid a recurrence of the trouble. In order to prove this, good material has been taken and similar failures have been produced at will by the same treatment. This has brought about in many shops as great an improvement in their methods of working the steel as in its manufacture. The net result of all this is that the consumer is to-day getting a better structure than ever before.

Recent careful scientific investigations have given us valuable information of the character and properties of steel, but there yet remains the important work of showing the direct relation between the results of these investigations and the every-day processes and results obtained in our mills and shops.

There is considerable room for improvement in our ordinary methods of testing structural steel. The conditions under which tests are made should be reduced to a standard as regards the pulling speed and the relation of the width of test piece to thickness of the material. About three widths would be sufficient to cover all ordinary thicknesses, and they could be used without materially increasing the cost of the present methods of preparing test pieces. We also need some simple machine for making impact tests, as our ordinary tension tests do not give us all the information required as to the quality of the material to resist shock.

Too much importance is paid to the quench bends. In some cases the cold bends have been entirely omitted and the quench bends considered a reliable test as showing the quality of the material. Now, this is all wrong, as soft steel which has been finished at too high temperature, and thus rendered brittle so that it will not stand the ordinary cold bends, may be restored by the heating, and the carbon being so low that the subsequent quenching does not harden this class of material, it then bends 180° flat on itself. Material accepted under these conditions has failed under subsequent shop work. Such material would have been rejected at the mills had the ordinary cold bends been made.

In the following I quote freely from my recent paper before the American Institute of Mining Engineers.

Regarding the specifications for material on export orders, it is a very different matter, as the engineers are at a distance and there is not always time to refer questions for their decision. In cases where the chemical requirements do not agree with the physical requirements specified, the inspector is sometimes forced to reject material that he knows from his experience is all right. It may give better physical tests than were called for but not conform to the chemical requirements in the particular specifications in question, though it would meet both the physical and chemical requirements of our leading engineers and railway companies in this country. Some of these foreign specifications are so worded, and the requirements are such, that it is not safe for an American manufacturer to bid on the orders. This may be due in part to their not understanding all of the conditions under which the tests are to be made. In other cases it seems as though modifications must have been made on previous orders, either in the chemical requirements or physical tests called for, as no steel was ever made that would meet all the requirements of chemical and physical tests in some such specifications.

Many export orders for rails call for phosphorus not over ·06 per cent., while the sulphur is allowed a much higher limit, or not specified at all. This low phosphorus cuts out several of our largest steel works, whose material will meet all of the physical tests called for, being low in sulphur and under ·10 per cent. phosphorus, and giving entire satisfaction to our leading engineers and railroad companies. The foreign manufacturers of basic Bessemer steel and low-phosphorus acid Bessemer steel are working the low-phosphorus clause for all it is worth, just as our manufacturers would do under similar circumstances; but we, as engineers, want to know if there is any good reason for this distinction, which is made on account of local conditions, and if the high sulphur is not as undesirable as the phosphorus would be up to the limit of ·10 per cent. usually allowed in this country?

This is a matter that should be thoroughly discussed, and on which opinions should be secured from our leading engineers; for it is of no use for the manufacturers to give their opinion unsupported by the experience of users of their rails. It is just here that the effect of the different elements plays an important part. Our manufacturers know from experience that as their phosphorus is a little higher than the limit of ·06 per cent. referred to, they must keep the other elements inside of given limits to produce the best results in the finished rails. This is done successfully, and a rail is produced that will meet the requirements of the drop-test and give satisfaction in use. I do not wish to be understood as advocating high phosphorus, but my position is, that rails which will meet all of the varying conditions in this country will meet all that is required of them when put in use in other countries. If one examines the methods of manufacture of rails in this country and those in other countries, then visits the countries where our rails are being introduced, and gets accurate information as to the service they are giving, he will be convinced that there is a great future for America in the export business in rails.

The conditions with regard to the material for bridges are about the same. Foreign specifications, in many cases, provide that only acid open-hearth steel can be used. This has already prevented our bridge-builders from bidding upon thousands of tons of bridge-work, although in some cases they have accepted the requirement of acid open-hearth steel, and have taken the orders. In other cases they have explained that our Government is using the basic open-hearth steel; that in the manufacture of it the works here start with an iron very much lower in phosphorus than is ordinarily used, and that the resulting steel is much more uniform. This has had a great deal of weight, and the use of basic steel has been allowed in some cases. In other cases new specifications have been adopted after investigation in accordance with the best American practice, which allows the use of either basic or acid open-hearth steel. I refer to this matter at length, as it is of the greatest importance to our engineers and manufacturers, as well as to all others who wish to see our export trade developed. It is of the greatest importance to establish the quality of American material abroad, and to have on record all facts regarding the same both from the engineer's side and the manufacturer's.

In September last, I read a short paper before the American Branch of the International Association for Testing Materials, calling attention to the manner in which our manufacturers are handicapped by specifications for export material, and I am pleased to state that they have decided to appoint a special committee to investigate and report on the use of basic steel for bridges, and the use of steel for rails, containing up to ·10 per cent. phosphorus. I trust that this Institute will be represented on that Committee as it has done such good work in the past on iron and steel. You are all, no doubt, more or less familiar with the work of the International Association for Testing of Materials; but Mr. Henning, one of the council, who is present, has kindly consented to explain in detail the objects of the Association and point out wherein the Mining and Metallurgical Section of the Franklin Institute can co-operate with them in their work.

MR. GUS C. HENNING (New York):—As long as eighteen years ago it was recognized in Germany that too little attention was paid on the one hand to proper qualities of materials for specified purposes, and on the other to the methods used for determining these qualities, which were so various and frequently vague, that prominent investigators began to compare notes for the purpose of determining upon some method by which improvements might be effected in these matters.

Hence eminent metallurgists and experimenters, with the late Prof. J. Bauschinger at their head, decided to meet in conference and present their individual views on the subjects to be discussed.

It was at once decided that there should be no constraint or compulsory action, and that all deliberations were to be embodied in resolutions taken and modified from time to time as opportunity, metallurgical change and the then knowledge required or made possible.

A few conferences showed the existence of a mass of incongruous methods and such a variety of constants for each kind of material that it became necessary to adopt or suggest standard shapes of test pieces and also methods of testing.

Tests had been made in such a variety of ways that any one variety of steel, for instance, apparently showed the most ridiculous differences in strength, elongation and other properties. Upon making tests on a uniform basis, it was found that there were still differences, some of which could and some of which could not be explained.

In this manner, recommendations for methods of testing and shapes of test pieces were made for tension, crushing, bending, impact, torsion and repetitive tests, so that at the present day results have become generally comparable, and the value of results stated is generally known.

Not only were the metals considered at these conferences, but cements, stone, paper, etc., etc., were discussed and their study referred to commissions for report at later meetings.

At the present time, however, our knowledge of the subject is so incomplete that no less than twenty-nine different problems have again been submitted to commissions for further inquiry.

During these conferences it had become apparent that it was not sufficient to study and discuss this subject from the points of view obtaining in one country, but that those existing elsewhere were equally important, especially when considering the demands and requirements of trade between various countries.

Numerous nationalities had already taken part in these conferences, until finally, in 1893, the United States was also represented, as your narrator was sent to Vienna to take part in the deliberations as representative of the American Society of Mechanical Engineers, as which he has since acted at Zurich in 1895 and at Stockholm in 1897. At Zurich the United States Government was represented by an army engineer officer, while at Stockholm both army and navy were represented.

At Zurich the French Government took part officially for the first time, and at Stockholm England also had representatives. Now the International Association for Testing Materials, which had crystallized at Zurich out of the previous conferences, numbers more than 1,500 members, and is growing rapidly. The American Section already counts eighty-five members, among whom are some of the most prominent steel works, and a number of the best known cement experts.

Among the twenty-nine problems which have been remitted to the sub-commission for further study and report, by the Stockholm Congress, are three which are of especial interest to sidero-metallurgists, and are at the same time of considerable commercial interest. Before mentioning these in detail, I desire to explain that it had become apparent to European engineers that there were other fields in which the Association could profitably work, besides the more abstract or strictly technical subjects of methods, standards, etc., etc., which had theretofore occupied its entire attention. Moreover the result achieved had been so satisfactory and the recommendations had been so generally adopted, that it seemed possible to make the deliberations of immediate practical value.

It had been felt that the use of materials for specific purposes was so heterogeneous and indiscriminate and the specifications under which they were to be made and inspected, so manifold, in many ways original, and showing the idiosyncrasies of individual engineers and corporations, that it was deemed the proper time to take up these subjects with the view of introducing system and method into this apparent chaos.

For this purpose, and with this in view, the following problems were proposed and have now been submitted to commissions for consideration, investigation and report:

(1) On the basis of existing specifications, ways and means are to be suggested for introducing international rules for testing and inspecting materials.

(2) Proposition to determine methods of determining the homogeneity of iron and steel, applicable for purposes of and at the time of inspection.

(3) Collection of information for the purposes of establishing standard piece-tests for the purpose of properly and rapidly inspecting lots of finished material, such as rails, axles, ties, springs, cast and wrought pipes and other finished parts of structures.

The chaos of specifications for material had already necessitated the arrangement of all iron materials into groups or classes, and this, as the processes of making the materials were few and very similar, did not offer many difficulties. The processes used in other countries had not been considered, as there was no person present interested in them, to present their differences and suggest the advisability of broadening the field of study so as to cover all processes used in any country. As the English had never taken any part in these deliberations, they had not become cognizant of the peculiarities of their own requirements and specifications, and have not even adopted approximately uniform methods of tests and shapes and sizes of test pieces, so that at the present time an English report of tests is the least valuable of any, because not made on a basis and standard, well known and clearly understood in every case, without special inquiry.

The first of the problems stated, now before the International Society, shows clearly that it is generally recognized that there is a multitude of varying specifications and rules for testing and inspecting materials, and that it is considered advisable to introduce some sort of uniformity. The object is, of course, to facilitate labors of the works and of the engineers, as well as to open the way to a clear understanding by all parties interested, of the intents and purposes of the specifications and their proper interpretation. Nothing is more annoying to the manufacturer and the user than misunderstandings in regard to the intent and meaning of some part of the contract after the same has been signed. Unfortunately, these details of contracts are rarely discussed in advance; and, in fact, in most cases this would not be possible, because it is common practice to contract to furnish a lot of steel by the hundred or thousand tons for "structural purposes, rails, ship-plates, etc.," without any statements as to quality, because it is assumed that this is a matter for easy later adjustment. When the time for the latter arrives, if, indeed, it is not left until the material is actually ready for delivery, then the trouble begins. If, however, a set of standard specifications were formulated, the difficulties would readily be eliminated, if prepared on a sufficiently broad basis, because the basis at least would in every case be well known.

At the present time it is recognized that there is such a general exchange of material between distant countries that it no longer suffices to prepare specifications which will answer either for Europe or for the United States alone.

The United States buy steel and iron in large quantities from Sweden, England and Germany. On the other hand, these same countries buy larger and larger quantities of materials from the United States.

However, the materials made in the United States are made from different crude materials and by methods differing from those used in other countries, and while the chemical compositions vary considerably, actual use of them on a large scale and experience under most varying and trying conditions have demonstrated their uniformly good and satisfactory qualities. Hence, while we know that American materials answer every purpose, they do not apparently comply with foreign specifications. Here the American national character has again made itself felt and in a most pronounced manner. It was found that our materials would produce a finished product which is not that fulfilling old specifications; nevertheless it was tried and in a short time was found to be satisfactory for many purposes and in many ways. This gave encouragement to use it on a larger scale, with similarly satisfactory results.

These results of practical experience were laid before American engineers, and specifications were at once modified to suit these new conditions, replacing the old by something better. In Europe this would be a very difficult and tedious procedure. If Americans desire to make any impression on conservative elements, we must submit all our facts and evidence in such manner and by such responsible and trustworthy individuals or organizations that credence will be given them wherever presented.

We now know that our materials answer every purpose, and, although containing what were formerly considered impurities (and are now known to be almost necessary admixtures), in this respect failing to meet some American and nearly all European specifications, fully comply with the requirements of actual use, and hence should be permissible in best construction.

It now depends upon proper and authoritative demonstration and elucidation of these facts, by careful collation of practical experience and tests under the direction of such reputable and well-known Institutions as the Franklin Institute of Philadelphia, to take up the subject in order to be able to present overwhelming array of facts obtained from practical experience, sifted and arranged in proper manner, with documentary evidence.

Such array of proofs presented to the International Association for Testing Materials would at once reach all of the authorities interested in the subject and would accentuate the necessity for revision of specifications for material with a proper regard to actual advanced conditions of the American steel industry.

It seems to me that no one would find a more prompt response in regard to collecting sets of specifications and reports of experience with material than the Franklin Institute. Hence, it would in my opinion, be a wise move for the Institute to enter upon a field of activity in which it would render immediate practical service in the interest of our most prominent industries. Co-operation of the Franklin Institute with the International Association for Testing Materials would no doubt advance the interests of both and lead to results practically valuable; it lies directly in the sphere of action laid down in the charter, and will have a far-reaching and beneficial effect in Pennsylvania, which is so largely dependent for its welfare upon the advancement and success of its metallurgical establishments, than which there are no more important in the world.

Mr. James Christie:—Mr. Webster's paper is a plea for some approach to international uniformity in specifications for steel. It is of especial interest now, when the manufacturers of Europe and America are competing in a common market for the trade of the world, and the interest manifested here and abroad in the International Association for Testing Materials indicates a desire to view the subject from some rational basis. So long as basic process steel is so prevalent in Germany and at the same time held under such a ban of suspicion in England, there is bound to be considerable divergence in specifications, and it affords engineers an opportunity to formulate demands favorable to the home producer. The interest of the purchaser being to get the best material for the price offered, it is our interest to convince him that the specifications we are able and willing to conform to, afford him sufficient protection in judging the quality of the material, and it is believed that the specifications of the leading railroads of the United States are sufficiently strict and exacting to meet any reasonable demand.

Those who have had an opportunity to observe the development of steel manufacture in this country will concede that there is much less friction between manufacturers and inspectors now than formerly, and further, that the average standard of quality has been decidedly improved. So long as rails are made from Bessemer steel by acid process we can hardly expect to fully meet the foreign specifications which Mr. Webster criticises, demanding phosphorus below ·06 per cent. Nor do I know that there is any valid reason why double that percentage is alone sufficient cause for rejection if the other constituents are satisfactory. Perhaps they are right in allowing a much higher limit for sulfur than for phosphorus for material that has not to be re-heated subsequently, as there appears to be no evidence of injurious effects following.

The rapid extension of the basic process in American open-hearth practice and its almost universal acceptance in our most important structures, coupled with the fact that the material but recently bore a stigma, remaining from early defects in the process and from the misapplication of materials, and hence was subjected to the most rigid inspection and scrutiny, indicate that this steel gives satisfaction and the process is thoroughly established. If, as we are told, the same condition does not exist in British manufacture, the fault must lie in the raw material used.

If the objections urged are only lingering prejudices, they will not last long, and the American manufacturer has only to maintain the standard of quality accepted at home and prove the reliability of his product to command the confidence and patronage of the foreign consumer.

MR. H. V. WILLE:—I cannot too strongly endorse Mr. Webster's remarks on the heat treatment of steel, especially those in reference to quench and ordinary bending test. A sample of steel recently came under my observation which, when judged by the tensile strength, reduction of area, elongation and chemical analysis, would be regarded as the highest grade of material, and, in fact, it passed two inspections on such tests. Notwithstanding the results of these tests, the plate cracked in numerous places between hole when an effort was made to roll to a 60-inch ring. A test was now cut from the plate, and failed, as you will see by this sample, on ordinary cold bend; but a second test cut from the same portion of the plate, when heated to dull cherry and quenched in water, bent flat without signs of distress, proving that a good plate of steel was injured by finishing at an improper temperature. The quality of the steel can be judged by the following tests:

Tensile strength, pounds per square inch =	59200
Elongation, per cent. 8 inch section =	28
Reduction of area, per cent. =	60·2
Carbon	·24
Manganese	·39
Phosphorus	·012
Sulphur	·020
Silicon	·020
Copper	trace

MR. A. A. STEVENSON, Burnham, Mifflin County, Pa :—I have read the paper on "Specifications on Structural Steel and Rails" with interest. I have had very little time to devote to the subject, but some of the following facts gathered from my own experience may be interesting to you.

You state that "the quality of steel depends (1) on its chemical composition; (2) on the treatment it received in the course of manufacture." I would go a step further, and say that, in my opinion, as far as open-hearth steel is concerned, the physical results, to a certain extent, depend on manipulation of the bath in the furnace.

Concerning the relations between the chemical composition and physical results, I must say I have been somewhat surprised to find how close this relation is. The point in question has been brought out strongly in test work we have recently done on some tires made for a foreign government to a rather difficult specification.

I heartily agree with the effort to have the conditions under which tests are made reduced, as far as possible, to a standard. In my own experience, I have found a great many tests that were practically valueless for comparative purposes on account of unknown or varying conditions.

I think it is desirable not only to have dimensions of test piece and pulling speed standard, but also important to have a record of the period elapsing between the time product is finished and tests are made. That a change takes place in steel after finishing, which materially affects the physical results, cannot be questioned.

In connection with above, the following figures may be interesting. Test pieces were all cut from tires and duplicate tests, as far as possible, from the same part of the tire, as, owing to section of a tire and process of manufacture, tests from different parts of same section show a variation.

Test.	Dimen.	Elast. Limit.	Ult. Strength.	Elong. Per Cent.	Reduct. Per Cent.	Remarks.
311160 A2	2 x ·500	53490	107460	15·	19·20	Pulled within 3 days after tire was made
311160 A2	2 x ·500	56037	108700	16·30	24·30	Ten days later.
311283 A2	2 x ·500	50940	99590	14·00	22·20	Pulled within 3 days after tire was made
311283 A2	2 x ·500	53000	103464	18·00	27·40	Ten days later.
311356 A2	2 x ·500	56037	111050	10·00	12·37	Pulled within 3 days after tire was made
311356 A2	2 x ·500	61130	111410	15·00	21·50	Ten days later.
319619 A2	2 x ·798	70370	121250	11·00	14·01	Pulled 5 days after tire was made.
319619 A2	2 x ·798	71980	121970	14·00	17·89	Seven days later.
318932 A2	2 x ·798	65080	121470	11·50	13·55	Seven days after tire was made.
318932 A2	2 x ·798	64400	121160	13·00	16·30	Fourteen days later.

Tests were all pulled at the same speed.

MR. JOHN STERLING DEANS, Chief Engineer Phœnix Bridge Company, Phœnixville, Pa.:—We are in entire sympathy with the effort to secure uniformity in the specifications of steel--such uniformity would be equally valuable to the engineer and manufacturer.

DR. CHAS. B. DUDLEY, Altoona, Pa.:—I am obliged for the outline of Mr. Wm. R. Webster's remarks before the Mining and Metallurgical Section on "Specifications on Structural Steel and Rails," copy of which reached me a day or two ago. I am sorry that I cannot promise to be present at the meeting.

I will only say, as voicing my experience now for some twenty years, that in my judgment improperly made specifications are the cause of more difficulty in the use of steel than any other single cause. On the other hand, properly made specifications are an absolute essential to the successful use of steel in large quantities. If I could be with you I should be glad to expand on this point at length.

MR. PAUL KREUZPOINTNER (Altoona, Pa.):—Mr. Webster's paper might be divided into three parts, each of which is important enough to form the topic for a separate discussion. The mill and heat treatment of steel of whatever kind is such an exceedingly complicated subject that it takes a large and varied experience, supplemented by much patient experimenting and examining, in order to be able to grasp the importance of the subject fully. In my paper, "Riddles Wrought in Iron and Steel," which I will have the honor to read before the Mining and Metallurgical Section of the Franklin Institute, I will return again to this subject.

Aside from this topic, Mr. Webster discusses the value of present specifications issued by consumers at home and abroad. The same remedy for possible defects in that direction applies to both these topics, namely, uniformity of methods of testing and analyzing. A satisfactory standard of quality cannot well be established before the establishment of uniformity in the methods of ascertaining the uniformity of such a standard. Structural steel stands a great deal of torture and maltreatment, more than the average consumer is aware of sometimes, as a consequence of which many a consumer swears to the unquestionable value of his specifications, or method of testing, or both, simply because his material or structure has not yet broken down. The consumer does not always seem to comprehend the fact that, because a material is safe, it is not also the most economical. Of course, large consumers will soon find out what they want and need, but there are comparatively few who have the necessary every-day experience and means to arrive at the proper conclusions. Thus uniform methods of testing would soon help the law of the survival of the fittest to weed out undesirable features in home and foreign specifications, but not before, because then not only the present quality of a structural material will be established, but largely also its economic value as far as durability is concerned. An engineer now specifies a given quality; this material is tested according to one of different methods, and is approved. But neither the specifications nor the method, standing alone and for themselves, is a guaranty that the least economical amount of material nor the most suitable quality has been used, and the question might be raised in such a case whether the final owner of the structure was not compelled to pay for more material than was necessary, or paid a higher price for its quality than was necessary; or paid for an inferior quality—a quality verging constantly on the edge of a breakdown, though unknown to all parties concerned. Uniform methods of testing have a tendency to bring the competitive qualities of materials to the surface, as it were, and this will naturally be followed by uniform specifications. Considered, therefore, from the standpoint of natural evolution, agitation for uniform methods, and the presentation of results of long established methods, having produced both economy and safety, should precede agitation for uniform specifications, because if we urge necessity of uniform, or any given specification, we should be able and prepared to bring positive or negative proof that such specification will give the best results. We cannot very well give such proof as long as a score of people raise their hands and each one asserts he is in the exclusive possession of the right and only method to furnish the desired proof. Next in importance is the question how much methods of testing may differ and yet producing practically uniform results. In commercial, testing and all scientific testing and analyzing serves only to give greater value and usefulness to commercial testing, the latter being the crucial test for the practical value of scientific work, such a difference in details is permissible, since the properties of metals vary more or less within safe limits and a certain amount of elasticity in methods of testing, as well as of the requirements of specifications, is not only desirable but necessary.

Stated Meeting, November 9, and Special Meeting November 23, 1898.

A STUDY OF THE MICRO-STRUCTURE OF BRONZES.

By A. E. Outerbridge, Jr.

At the stated meeting of the Mining and Metallurgical Section of this Institute held in May last, Mr. Guilliam H. Clamer read a very interesting paper on the "Micro-Structure of Bearing Metals," which was embellished with a large number of excellent photo-micrographs. In the discussion which followed, I stated that I made some microscopic examinations of standard silver alloys (900 parts of silver, 100 parts of copper) twenty years ago, with the view of endeavoring to obtain light upon the phenomenon known as "segregation," but met with little success.

The science of microscopic metallography was, at that time, in its infancy, but since then it has attained a high degree of development in the hands of eminent investigators in Europe and in this country. Among these are M. F. Osmond, Professor Le Chatelier, Dr. Charpy and others, of Paris; Prof. A. Martens, of Charlottenburg; Dr. Wedding, of Berlin; Mr. J. E. Stead, F.C.S., of Middlesborough, England; Mr. Albert Sauveur, of Boston, besides many others. The literature upon this subject, chiefly found scattered through the reports of various technical societies during the past ten or fifteen years, is very extensive and most valuable to the student.

A few years ago I began to study the micro-structure of cast iron, and I encountered certain difficulties which, so far as I know, have not been described or satisfactorily explained as yet. Cast iron is, as you all know, a complex alloy, or, perhaps, to speak more accurately, it may be described as a metal containing a number of dissimilar elements, such as carbon, silicon, sulphur, phosphorus, manganese and traces of rarer metals and metalloids, partly united in chemical union with iron, as in the case of "combined" carbon, and partly held mechanically diffused through the mass, as in the case of "free" carbon, which is so loosely held in the spaces between the crystals that it may be readily brushed out from a freshly fractured surface.

Two important sources of error in observation or deduction presented themselves in this study. One of these relates mainly to the remarkable influence that the rate of cooling of a mass of molten cast iron exerts upon the molecular structure of the metal. The other has to do with changes in appearance under the microscope of polished and etched specimens caused by variations in strength of acid, length of time of immersion, etc.

With respect to the first observation, I found that different portions of one specimen revealed differences in molecular structure, so that a photo-micrograph taken from the center of a piece might present quite a different appearance from that of a similar picture taken from a point nearer the edge of the specimen. This difference was apparent even in sections of quite small castings, and it may safely be asserted that cast iron differs radically in this respect from cast steel, which is more nearly homogeneous throughout the mass.

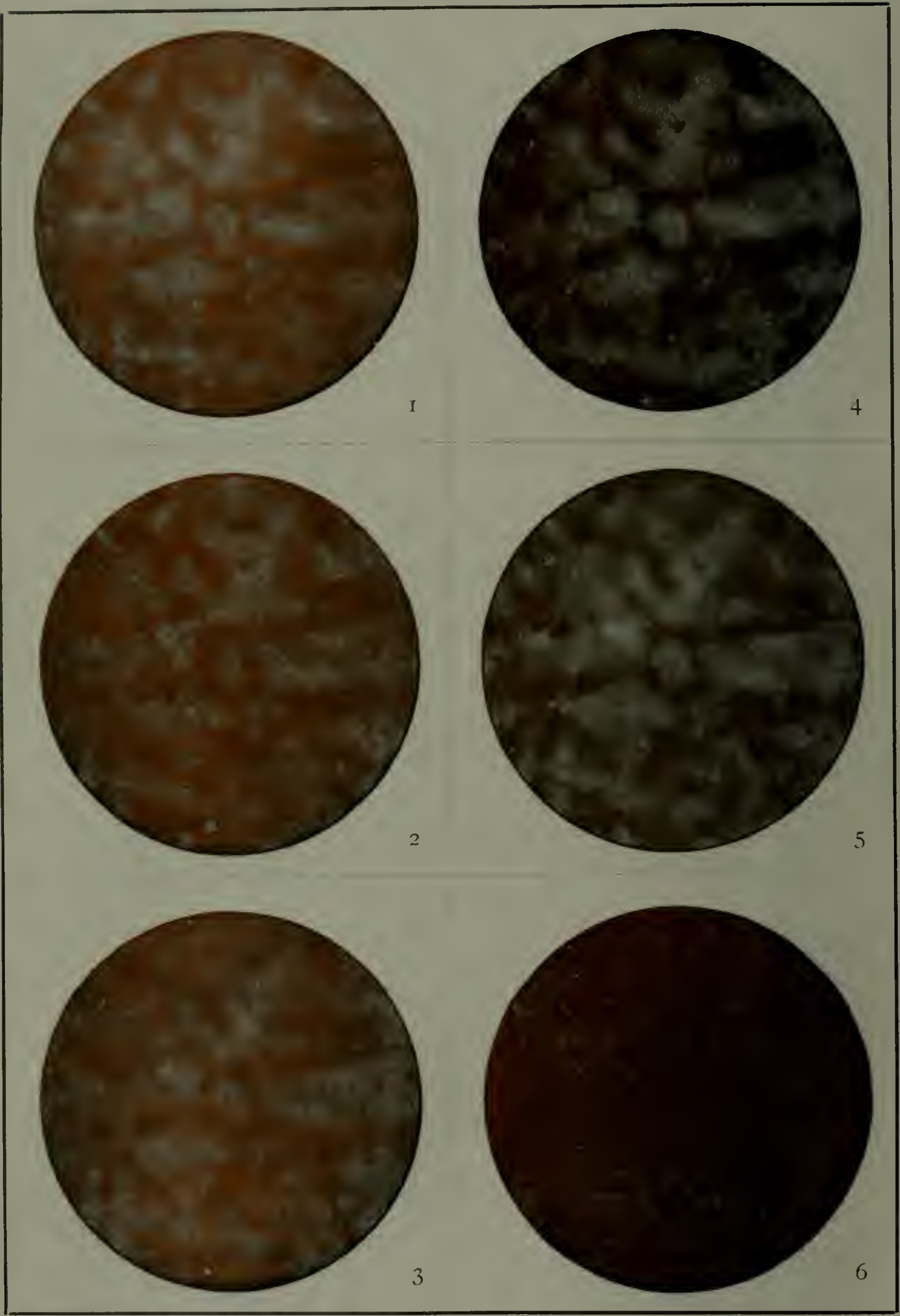
With respect to the second point, I found that a change in strength of acid, or in the time of etching, sometimes produced so great a change in the appearance of the surface that misleading conclusions might readily be drawn therefrom. In order to study this matter carefully, I etched a small piece of gray iron and also a piece of white iron taken from the same casting, and studied the structures microscopically, then repolished and re-etched the pieces many times. I have several photo-micrographs taken from these specimens, and the apparent differences in structure are greater than would seem to be properly attributable to the known variations in treatment. Further comment upon this matter must, however, be deferred for the present; reference is made thereto in this place merely for the purpose of explaining the reasons that led me to make the examinations now about to be described, which are here presented tentatively, and in an incomplete stage, for the purpose of inviting discussion and criticism from those present, some of whom, I know, have gone more deeply than I have been able to do into the study of the micro-structure of bronzes.

Recently I have been engaged in examining in various ways a large number of specimens of bronze metal cut from small castings, with the view of endeavoring to obtain denser or finer grained and more homogeneous metal. The specimens (about ninety in number) were of two sizes from each melt; one was a flat disk about 1½ inches diameter, ¼ inch thick, the other was a cylindrical piece about ¾ inch diameter and ½ inch thick. A number of these pieces were polished on one face, etched in weak muriatic acid, and others were etched in nitric acid, using generally one part of acid to nine parts of distilled water for microscopic examination. While I was engaged in this preliminary work, a photographer of this city, Mr. Fred. D. Maisch, called to show me some photo-micrographs of pathological specimens and of sections of steel that he had made, stating that he desired to make a specialty of such work, although disclaiming any expert knowledge of metallurgy. Being pleased with his exhibit, and wishing to encourage him, I gave him a few of the unpolished bronze disks, numbered for identification, without any information as to the character of the metal or the object of the investigation, neither did I make any suggestion as to the polishing or etching process; I merely stipulated that all of the specimens should be prepared for photographing in precisely the same way.

The results produced were satisfactory to me, and the differences in micro-structure as shown by the photographs accorded with my expectation, knowing, as I did, the difference in treatment of the metals in the crucible.

Then Mr. Maisch expressed a desire to make some other photo-micrographs if I would furnish the specimens and propose a scheme of study.

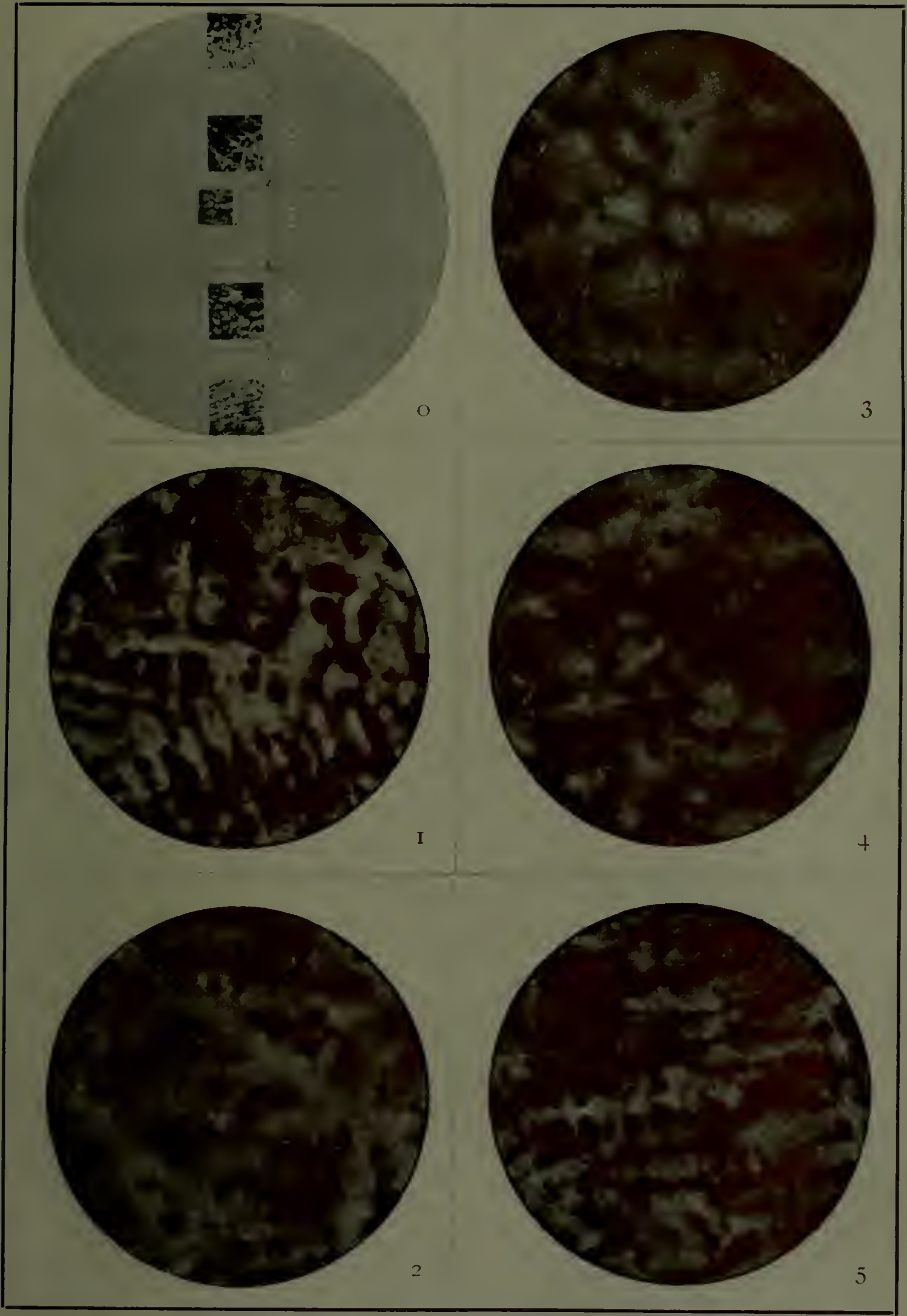
I told him of my former observations with cast iron, and suggested that he should re-etch one of the bronze pieces which he had already photographed for me, then make a new negative from the same portion of the specimen, noting the time of immersion, strength of acid, etc.; and if he ob-



[illegible], PHILADELPHIA

PLATE NO. 1.—FIRST SERIES.

Successive etchings. Cent. etched as long as comp. experiment. Magnification 70 x



LEVY [illegible] PHILADELPHIA

PLATE NO. 2.—SECOND SERIES.

Completed experiment. Photographs numbered as in diagram. Magnification 70 x

served any decided change in appearance in the photograph to repeat this operation two or three times. This, h has done, making six separate exposures upon the same spot, after six separate etchings, varying the length of time of immersion and strength of acid. Mr. Maisch has also made lantern slides from these negatives, so that you can see the process of development of the structure very clearly. (See *Figs. 1, 2, 3, 4, 5* of the first series, and *No. 3* of the second series.)

The disk selected for this purpose showed in the first photograph certain characteristic groupings of dark bands, which I believe to be the so-called "eutectic alloy," and these markings can be easily recognized in each picture, but it can also be observed that considerable modification in the general appearance has been produced by the difference of treatment. If it were not for this fortunate means of identification of the specimen, I think that an observer might be pardoned if he should imagine that the photographs were made from different specimens.

While I am not at liberty to give the exact composition of this metal, which was made for commercial purposes, I may say that all of the specimens under estimation were similar in character, and they may be described in general terms as 10 per cent. alloy; that is, copper-bronze containing from 7 to 10 per cent. of tin, and usually a small percentage of zinc and a small quantity of lead added just before pouring.

In the second series of experiments two parallel lines about $\frac{1}{4}$ of an inch apart were drawn across the face of the etched specimen, the space between the lines was then divided into five squares; photo-micrographs numbered 1, 2, 3, 4, 5, corresponding with the section numbers, were then taken, as shown in the diagram (*Fig. 0*). Pictures 1 and 5 show portions of the disk at the extreme edge, while numbers 2, 3 and 4 were taken from near the center of the squares. The actual size of each spot photographed was less than $\frac{1}{16}$ of an inch, and the negatives are $3\frac{1}{2}$ x $4\frac{1}{2}$ inches. The half-tone engravings are 2 inches in diameter, and represent sections from each negative.

The dark bands in these photographs are, in reality, sharply defined lines when examined under the microscope. By focusing very carefully it was discovered that these portions are in relief, and when a strong side light is cast upon the specimens it was found that quite perceptible shadows were cast; this is more noticeable in the deeply etched specimens.

I think it can be observed in the photo-micrographs that the bands are more numerous, and more closely knitted together, near the edges of the disk, than they are towards the center, and I regard this as an evidence of liquation or segregation of the eutectic alloy towards the outer portion of the casting. In other words, the fusing point of the eutectic alloy being lower than that of the mass, this alloy is driven or distilled out from the hotter portion of the metal when cast.

Dr. Charpy, in his "Microscopic Study of Metallic Alloys," says, in relation to copper-tin alloys, in which the copper largely predominates: "It was found that the rate of cooling had a marked influence upon the proportion of the eutectic alloy present in the metal.

"In quickly cooled alloys the eutectic mixture may even disappear almost completely, notwithstanding the presence of some 7 or 8 per cent. of tin, while in slowly cooled alloys, containing only 2 or 3 per cent. of tin, a certain amount of the eutectic alloy is readily discernible." Tests which I have made seem to fully corroborate Dr. Charpy's statement regarding the effect of rapid cooling of an alloy containing approximately 7 per cent. of tin.

The illustration No. 6 in Plate No. 1 shows a photo-micrograph of a bronze cent (copper, 95 per cent.; tin, 3 per cent.; zinc, 2 per cent.). The design upon one face of the coin was obliterated by filing the metal to a flat surface, and the disk was then polished and etched. It will be observed that the molecular structure is very different from that of the other bronze specimens which have not been subjected to pressure under the rolls and coining press. The crystals are much finer and the metal is apparently more homogeneous, for there is an absence of the irregular bands of the eutectic alloy so conspicuous in all of the cast bronze specimens.

This is, perhaps, partly owing to the fact that coin ingots are always cast in iron molds and the metal is thus suddenly solidified, while all of the other specimens were cast in sand molds. This observation may have practical value.

The conclusions to be drawn from these investigations, assuming the premises to be correct, may be summed up as follows:

(1) Variations in treatment of specimens cause variations in the results, which may be misleading, and it would, therefore, seem to be desirable that some uniform system should be adopted by all investigators in this field.

(2) The rate of cooling of a mass of metal affects the micro-structure so that two specimens from the same ladle of metal, one taken from a small casting quickly cooled, the other from a larger casting slowly cooled; or two micro-photographs taken from different portions of the same specimen may show variations in micro-structure that may lead to error.

It is desirable, therefore, that some uniform size of specimens should be selected by micro-metallurgists as a standard with which to make comparisons.

In conclusion I wish to say that I am indebted to Mr. Maisch for the careful way in which he has carried out my suggestion.

Description of Plates. First Series.—(1) Plunged into strong nitric acid three times, two seconds each time, washing in liberal quantities of water after each immersion.

(2) Etched five minutes longer in 10 per cent. nitric acid.

(3) Etched ten minutes longer in 10 per cent. nitric acid.

(4) Etched fifteen minutes longer in 10 per cent. nitric acid.

(5) Etched thirty minutes longer in 10 per cent. nitric acid.

(6) Etched one hour forty-five minutes longer in 10 per cent. nitric acid, or two hours forty-five minutes, all told, in 10 per cent. nitric acid.

Nos. 1, 2, 3, 4, 5 of the Second Series were submitted to same treatment as the 6th of the first series, which is described in the text. It represents the coin.

DISCUSSION.

MR. PAUL KREUZPOINTNER [Altoona, Pa]:—I regret very much not to be able to attend the meeting of Wednesday, the 23d inst. Nor does pressure of business and short space of time allow me to write any extended and satisfactory discussion. I am glad Mr. Outerbridge has raised the points to be discussed, since the subject under discussion is a very timely one. There appears, as Mr. Outerbridge points out, to be considerable vagueness and uncertainty of mind prevailing as to what the microscope is really good for in metallurgy. Moreover, there seems to be an entire absence among those who do use the microscope in that direction, of an understanding of the imperative need for uniformity of methods for the purpose of making microscopic examinations of metals. That the microscope can be made a valuable and very useful auxiliary to the chemical and physical laboratory of steel works, foundries and large consumers of metals there is no longer any doubt. How to make this new auxiliary most practically useful is a matter of time and understanding how to use it and when to use it. But it will never attain its full usefulness unless the advocates of the use of the microscope for metallurgical purposes bestir themselves and join hands with the committee appointed by the International Association for the Unification of Methods of Testing, to agree on some practical method for making microscopic examinations of metals. This is just as necessary as the need of uniformity of methods in the chemical laboratory and the physical testing room. The manner of preparing specimens, the kind of acid used, the strength of the etching fluid and time of immersion for etching, are all factors which, singly or collectively, influence the final results of the microscopic examinations of metals. Hence, without A, B, C and D use uniform methods their work is not comparable, and may even become misleading. Or, if one of them is right and the others faulty, which one is right. and who will decide who is right? Let a controversy arise between producer and consumer, the operation of dispute to be settled by a microscopic examination of a given metal. If an expert is called on in the matter, then the contending parties are interested to know what standard structure of quality the expert bases his decision on and how he arrived at concluding this to be a suitable standard. Imagine several experts are called on, as is sometimes done in chemical analysis or physical testing, and each one reaches another decision, due simply to each one following a different method. The writer knows already of a case where the microscope was to decide the commercial value of a material, but it did not; not because the microscope was not the proper means, but because there were no means of comparing results.

MR. G. H. CLAMER (Chemist to the Ajax Metal Company): —I wish to corroborate the statements made by Mr. Outerbridge regarding the different structures observed by him in his study of bronzes by varying the conditions of etching, etc., and also the different structures observed in the various parts of the same bronze castings.

The alloy of copper and tin is one which is especially subject to segregation, and the appearance of the so-called tin stains or tin spots have long menaced the skill of foundrymen. These tin stains are nothing more than the liquated alloy, containing a high percentage of tin, and are very frequently seen on the fracture or on the polished surface of bronze castings, without the aid of the microscope.

The difference in the structural appearance of pieces of bronze examined by Mr. Outerbridge are undoubtedly due to phenomena of liquation which exhibits itself in varying degrees in most alloys. The so-called constant or chemical alloys being alone exempt from this disintegration.

The segregation of the copper and tin or bronze alloy has been carefully studied by many prominent scientists, notably Riche and Thurston, who studied the specific gravity and expansion and contraction of some fifty different atomic combinations of these two metals, with the result that when the alloy $SnCu_3$ was reached, it possessed the maximum specific gravity (8·91 according to Riche and

8·97 according to Thurston) together with the maximum contraction. Copper, according to Thurston, having a specific gravity of 8·791, and tin 7·293, it will be seen that the alloy $SnCu_3$ has a specific gravity greater than pure copper; this is also true of all alloys between 22 and 38·29 per cent. of tin. Below 22 per cent. of tin and above 38·29 per cent. the alloy—as would naturally be expected—becomes specifically lighter as it reaches pure tin.

The alloy showing the greatest specific gravity, together with the greatest contraction when this atomic proportion $SnCu_3$ has been reached, goes to prove the existence of a chemical combination in these relative proportions. The existence of such a combination seems also to be proven by the microscopic researches of Charpy and others, while recent investigations, by John E. Stead, of alloys containing a large excess of tin point to such combinations as $SnCu$, $SnCu_2$, $SnCu_3$ and $SnCu_4$. Crystals having these formulæ are claimed to have been isolated by Stead in alloys successively increasing in copper content. He used dilute nitric acid, which dissolved the remaining part of the alloy, leaving crystals having these definite compositions coated with hydrated meta-stannic acid. This was easily removed by dilute hydrochloric acid, and then upon examination the crystals were found to be lustrous, sharp and apparently in the form of square prisms.

According to earlier investigation, Kunzel claims that all alloys containing over 95 per cent. copper are constant, as is also the alloy of 17·7 per cent. tin and 82·3 per cent. copper, or ($Cu_{17}Sn_2$). Riche also found in this alloy but little liquation, and claims the alloy $SnCu_4$ to be constant as well as $SnCu_3$.

From the foregoing data it will be seen how diversified are the opinions regarding the segregation of the copper and tin alloys and also how complicated are its combinations. Certain retardations in the cooling curve of the copper and tin alloy were observed by Professor Roberts-Austen and Mr. Stanfield, and rather strengthened the view of Stead that in alloys which have more copper than is sufficient to made $SnCu$ may be mixtures of molecules of that composition, with other molecules, containing a larger atomic proportion of copper.

But since such segregation of chemical combinations are influenced greatly by external agencies, it is not surprising to find contradictions regarding their composition even in the statements of reliable investigators.

The conditions influencing segregation apart from the composition are temperature, duration of the liquid state, the size of the casting, mode of stirring and perhaps other influences not yet understood.

Liquation may take place not only with alloy cooled from the liquid state, but also in the alloy which is carefully heated to the melting point of the most fusible alloy. I recently discovered a very interesting example of liquation occurring under the latter circumstances. It occurred in a driving-box of an engine on the Chicago & Great Western Railway. The alloy in question was one such as is used for bearing purposes, and contained according to analysis:

Copper	77·05
Tin	11·75
Lead	10·82

This metal was cast into what is known as a "liner," which is simply a lining 1½ inches thick, to be placed inside of the driving-box of cast iron, serving in place of babbitt metal, which is used on bearings not carrying so great a load. Great trouble was experienced in getting the engine to run cool, and it was at last decided to remove the bronze liners for inspection. The cast iron driving-box contained a hole for some purpose (what that purpose being I do not know), and upon examination of the liner, it was found that the metal had been so heated by friction that it had actually melted and squeezed out on the sides of the axle and into the hole in the iron box. The piece which had squeezed into the hole was about ⅝ inch in diameter by 1¼ inches long. I at once noticed by its great hardness and peculiar color that its composition must be different from the remainder of the alloy contained in the liner. Instead of finding it an alloy largely made up of lead, as the writer had expected to find before trying its hardness, it gave the following analysis at its base:

Copper	76·20
Tin	22·06
Lead	1·80

While at top there was a little globule of metal which, of course, represented the first part of the alloy brought to the state of fusion, which gave an analysis confirming Charpy in his analysis of the eutectic, which this clearly represented.

Copper	74·06
Tin	23·22 (by difference)
Lead	1·92

Although this alloy contained lead, it appears to replace only the tin, as the eutectic of copper and tin according to Charpy is about 74 copper and 26 tin. Another peculiar feature of the mixture was that it was exceedingly hard to break up with nitric acid, thus also pointing to the existence of a definite compound.

It appears to me that this accidental mode of isolating the eutectic in alloys suggests an easy method for their separation, that is to heat the alloy under pressure, allowing some crevice or hole in the piston into which the eutectic alloy may find its way. The writer intends making some further investigation on these lines.

That this isolated alloy is a true eutectic was further evidenced by its structure under the microscope.

Owing to the segregation of alloys and of iron and steel, which may also be considered as alloys of iron with sulphur, carbon, etc., and the consequent lack of homogeneity due to the complexity of influences governing this condition, it would be exceedingly hard, if not impossible to designate any particular structural appearance as a standard by which to gauge all others of similar composition. It appears to me that microscopic examination can at best be but a science built upon comparisons when based on standard methods as suggested by Mr. Outerbridge and should go hand in hand with chemical analysis.

Structure (as I have said before) is affected not only by temperature of pouring, rate of cooling, or in other words, heat treatment, but also by the size of casting, and method and time of etching, etc., and for this reason I agree with Mr. Outerbridge in his statements regarding the necessity of standard methods.

I recognized these facts in my study of bearing alloys of copper, tin and lead, the results of which I gave in a paper which I read before this Section in May. My specimens were cut from the center of bars 1⅜ inches diameter by 6 inches long, into which size bars all the compared alloys were cast, being careful to have all the conditions as nearly alike as possible, manner of ramming, sand, venting of moulds, temperature of pouring, rate of cooling, time and manner of etching, etc.

Should the micro-examination become a practical technical mode of testing metals, it can be made so only by the use of standard methods, and it but remains to further the suggestion of Mr. Outerbridge on this point by the establishment of such standards.

MR. OUTERBRIDGE:—In summing up this interesting discussion of my paper, read at the last meeting of the Section, entitled "A Study of the Micro-structure of Bronzes," I wish to say that I am gratified to hear such unanimous expressions of agreement, coming from experienced workers in this field of investigation, upon the two principal suggestions contained in the paper, viz.: the desirability of the adoption of uniform methods of preparing specimens for the microscope, and of fixing upon standard sizes of test pieces. This, of course, does not mean that the investigator must confine himself to specified methods of treatment or to special sizes of specimens, but whenever such standard methods and sizes shall have been adopted by micro-metallurgists, the effects of variations of conditions upon the micro-structure of metals can be better understood and more readily explained.

After deciding in 1895 to again take up this microscopic work (after a lapse of over fifteen years), I procured copies of nearly all of the papers which have been published in the proceedings of various metallurgical societies bearing upon the subject, and also corresponded with some of the leading experts in Europe and in this country. I now have upon the table several interesting letters received in reply to the inquiries.

These queries referred particularly to treatment of cast iron specimens, but the principles and precautions to be observed, are much the same whatever metal may be under examination.

Mr. Thomas Andrews, of Sheffield, whose work in the micro-study of steel and iron is well known, says: "I consider that there need be no doubt as to the accuracy of microscopic observations if properly conducted. It is always best to work with direct light and down through the objective (the objective glass thus becoming its own condenser). Reflected light will give you a false idea of the structure, owing to reflection from crystal facets." This I have found to be quite true in my experience and I have, therefore, adopted the vertical illumination, using oblique light only for special work, and where it is desired to obtain certain effects.

The objective which I use is similar to that employed by Professor Martens, and devised by Mr. Natchet, of Paris, for the use of the International Commission on the Meter; it contains a small prism in the objective tube set opposite an opening or window in the side of the tube at the angle of total reflection. By focusing a beam of light upon the prism through the opening in the tube, the light is projected down through the objective upon the specimen, illuminating the field brilliantly. By closing the shutter the vertical light is cut off and the specimen may then be illuminated by a side light; this is a very convenient arrangement.

Mr. J. E. Stead, of Middlesborough, Eng., says: "I think it would be advisable to polish such metal sections (referring to cast iron) upon pitch; as is done by Professor Martens."

I am also indebted to Mr. J. E. Keeley, of this city—an enthusiastic microscopist whose skill in preparing thin sections of minerals and other specimens is known far and wide—for valuable information pertaining to the subject.

It should, of course, be understood that some of the specimens photographed and illustrated in this paper have been intentionally "over-etched" for the purpose of showing the effect of such treatment.

While listening to the debates this evening my attention has been called by Mr. Webster to the fact that one of the subjects to be discussed by the International Committee on Testing Technical Materials, is that which we have here advocated; a paper having been announced in the program to be read by Mr. Albert Sauveur, of Boston, editor of the *Metallographist.*

CHEMICAL SECTION.

Stated Meeting, November 15, 1898.

[ABSTRACT.]

AGRICULTURE IN THE HAWAIIAN ISLANDS.

By Dr. Harvey W. Wiley,
Chief Chemist of the U. S. Department of Agriculture.

DESCRIPTION OF THE HAWAIIAN ISLANDS.*

The island of Hawaii, which gives the name to the group, is the largest of the series, embracing about 4,210 square miles of surface.

The island of Hawaii is more than five times as large as the largest of the other members of the group. The three most important islands after Hawaii, together with their areas, are as follows: Maua, 760 square miles; Oahu, 600 square miles; and Kauai, 590 square miles. The total area of the four large islands of the group is 3,110,000 acres. The other islands of any agricultural importance are as follows: Molokai, 270 square miles; Lanai, 150 square miles; Niihau, 97 square miles; and Kahoolawe, 63 square miles. The total area of the islands where agriculture is possible is 6,740 square miles. There are hundreds of other islands connected with the group, but they are mostly barren rocks, and at present have no agricultural significance, with the possible exception of those where birds collect in great numbers, and where the carcasses of birds, as well as the eggs which they deposit, are valuable for fertilizing purposes.

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*The lecture was illustrated with stereoptic photographs of the landscapes and crops of the Islands.

The whole territory embraced by the Hawaiian Islands is included between longitude 154° 40′ and 160° 30′ west, and latitude 22° 16′ and 18° 55′ north. The extreme northern limit of the islands is therefore a little south of Key West, but, owing to the prevalence of the northeast trade-winds, the climate of Hawaii is probably the most grateful of any tropical climate in the world. The temperature at Honolulu rarely rises above 90°, nor does it fall below 54°. A case of sunstroke has never been known on the islands. White men can work in the open air and upon the farm in all parts of the islands, and this is not possible in other tropical countries.

The prevailing winds are the northeast trades. These blow for about nine months of the year. The islands possess a healthy climate. There are no virulent fevers such as are encountered on the western coast of Africa and in the West India islands. The island of Hawaii has been formed as the result of the action of four great volcanoes which are now extinct. The present active crater of Kilauea is evidently of too recent formation to have played any important part in the formation of the island. By the successive eruptions of the old volcanoes, and the cooling of the lava thrown out, mountains of lava have been formed by the four chief craters of the following respective heights: 13,805, 13,675, 8,275 and 5,505 feet. These peaks lie at an average distance of about thirty miles each from the other. It is evident that at first the spaces between the volcanoes were covered by the sea, but by the gradual degradation and overflow of the lavas these valleys have been filled up, and now in some places lie as high as 3,000 feet above the sea level.

From a geological study of the volcanoes it is evident that as they grew higher they opened lateral craters, due to the pressure upon the top of the crater. It is due to these lateral craters, largely, as well as to disintegration of the lava thrown out from the central one, that the intermediate spaces between the volcanic centers were filled. One of these lateral craters was developed from Maunaloa in 1868, when a stream of lava poured down to the sea, making the water very hot to a distance of more than a mile from the shore, and killing all living things in contact with it. Dr. Maxwell observes that "in the space of a day's ride he noticed no less than eighty-nine of these lateral cones, and observed mounds covered by forests on the mountain slopes which suggested many more. Each one of those in its day and measure was a center of eruptive force. Lava in some form came from their throats, and fumes of acidulated steam escaped from fissures in the lavas in their localities, leaving marks of their action of disintegration which are not difficult to distinguish. This distribution of centers of eruptive action gives to the valleys dividing the great cones the true character of vast volcanic plains."

CHARACTER OF HAWAIIAN SOILS.

The typical soils of the Hawaiian Islands have been carefully studied by Dr. Walter Maxwell, formerly one of my assistants in the Chemical Division of the Department of Agriculture, and for some years past the director of the agricultural experiment station which has been founded by the planters of the islands.

From a study of the geology of the Hawaiian group it is evident that these islands are entirely of volcanic origin. Professor Dana says in regard to them, "The Hawaiian Island group is a sample of a line of great volcanic mountains. Fifteen volcanoes of the first class have existed at different times and been in action along the line." The group of islands therefore represents that portion of the great mass of matter due to volcanic action which is projected above the water level. Doubtless these islands are connected by ridges of volcanic matter which perhaps have never been above the surface.

The character of the original rocks composing the islands is therefore evidently that of lava in general. The rock formations are not sedimentary, but have resulted from the cooling of the lavas which have been projected from the volcanoes. This at least is true as far as the surface of the mountains is concerned. The great up-lift forming the ridge probably was due in part to the ordinary causes producing mountain ranges, namely, the cooling and shrinking of the earth's crust. For agricultural purposes, however, the lavas are the only rocks which are to be considered, since it is from the decomposition of these lavas that the soils of the islands have been formed. The lavas have resulted chiefly from the fusion of rocks of basaltic nature, and hence the composition of the original lavas is such as would be produced by the fusion of basalt. The differences between the lavas and basalt would simply be those due to igneous action on fused basalt exposed to the air. The Hawaiian lavas resemble in their chemical constitution the basalts existing in the United States. A comparison of the analyses of a great number of lavas with a great number of American basalts is given in the following table:

Materials.	Analyses.	SiO_2.	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hawaiian Lavas	18	47.90	18·23	13·36	8·99	6·05	2·20	1·50
American Basalts	20	49·15	15·66	9·50	8·29	7·90	2·84	1·90

In the above table the analyses of lavas were made by Dr. Maxwell and his assistants, and of basalts by Prof. F. W. Clarke, of the United States Geological Survey, and his assistants.

FORMATION OF SOILS FROM LAVAS.

The formation of soils from lavas takes place under practically the same conditions which attend the weathering of ordinary rocks in the formation of common soils. All rocks, when exposed to the chemical and physical action of the forces which are found on the surface of the earth, suffer disintegration. Some kinds of rocks, of course, disintegrate much more rapidly than others, but all are affected. Soil, from an agricultural point of view, is the *débris* of rocks mixed with decayed organic matter. The forces which act upon rocks and lavas are many. Some of the more important ones only are mentioned here.

First of all may be considered the merely physical attrition. The beating of the rain, the eroding action of running water, the friction of the wind, and the grinding of particles of dust projected against the rocks, all tend to the same end, viz., the reduction of the rocks to fine particles.

The action of bacteria is also helpful to the disintegration of rocks. Even in localities in high mountains, where it would be supposed that bacteria did not exist, it has been found that fragments of rock are permeated to a greater or less depth with these organisms. In the exercise of their vital functions the particles of rock in contact with them become eroded, and are gradually rendered easy of degradation by other forces. Especially are the nitrifying bacteria active in erosion of this kind, since whenever they exercise their true vital function nitric acid results, and this acid acts rapidly upon most rocks in effecting decomposition. Even on rocks which seem almost bare, certain mosses and lichens are found to grow, and the vital activity of these vegetable growths rapidly affect the texture of the rock. It has been repeatedly shown that rocks, especially carbonates, when in contact with the rootlets of plants, suffer solution in all parts of contact. The growth of mosses and lichens in like manner disintegrates the rock and renders the processes of comminution easy. In the decay of organic matter, especially under the action of organisms, large quantities of acids are formed, which are carried into the rocks by the rains and help to dissolve them. The action of nitric acid has already been referred to. The action of carbonic acid which results from the oxidation of organic matter, is also powerful in effecting the disintegration of rocks. When the processes of soil formation have once started and small quantities of rock *débris* are formed, the growth of larger plants and the existence of terrestrial worms and insects help a still more rapid disintegration. In colder countries and on mountain peaks, where the temperature at times falls below freezing, the expansive force of water passing into the form of ice often helps to split up the rocks into smaller fragments. Inasmuch as many of the rocks are formed in conditions where metallic compounds tend to be reduced to a metallic state or to a lower degree of oxidation, it is found that the oxygen of the air itself is a powerful disintegrating agent. It is carried into the exposed rocks either in the air itself or by water, and in oxidizing the lower to a higher oxid, or metals to the condition of oxids, powerful disintegrating influences are exerted. It is under these and similar influences that the lavas which have flowed out over the surface of the Hawaiian group have gradually been converted into soil.

In the regions of active volcanoes water has acted in a more powerful way, because it is forced into all the crevices by the steam rising from the volcanic action. The heavy rains, which often occur in those vicinities, fall into the craters of the volcanoes, and reappear as steam. It is probable, also, that subterranean passages admit water to the regions of great heat whence the lavas come, and the water thus admitted is converted at once into steam, and finds egress through the crater of the volcano and through all the crevices communicating therewith. In many parts of the islands this action of steam on the exuded lavas may still be seen.

The general nature of the various craters in their original form may be surmised by a study of one of more recent origin. The crater of Kilauea is 3,972 feet above the sea level. The area enclosed within this crater is 2,650 acres. This was doubtless in the not very far remote past a lake of liquid fire. The actual area, however, which is covered by melted lava at the present time is not more than 50 acres. Throughout the whole area of the crater, however, volcanic evidences may be seen. It is stated by Dr. Maxwell, who has made a careful study of this locality, that in the morning before sunrise, when the temperature is low, a large part of the floor of the crater is concealed by condensing steam which issues from fissures and fractures in the lava which have been produced by partial cooling. In some instances the condensing steam shows an acid reaction to litmus paper, and in a few instances the steam was found to be extremely acid. Over the areas covered with steam it was noticed that there were deposits of materials which would be brought up through the fissures, and wherever this acid steam came into contact with the surface, evidences of rapid solution were seen. In one case, where a quantity of the steam was condensed and preserved for analysis, it was found to contain 4·92 per cent. of sulfuric acid. This steam contained no chlorin, showing that the sea water does not have ingress to the sources of volcanic activity. In the opinion of Dr. Maxwell, the action of this acidulated steam is one of the most important of the factors concerned in the disintegration of the lavas in the islands. In order to determine the effect of this action alone, as separate from that of surface forces, Dr. Maxwell removed the overlying slabs of lava and secured blocks from below which had never been exposed to surface forces, but only to the action of the acidulated steam mentioned above. At the time of taking the specimens the blocks were so hot that the hand could not touch them. Two of the larger specimens were found partially studded with crystals of sulfur. Where the steam has eaten out cavities in the blocks they were found partly filled with crystals of gypsum and alum. Over the surface and within the blocks iron was found oxidized and collected in pockets of red ochre, while the silica was separated into distinct masses of so-called yellow ochre. The process of decomposition was found to continue after the blocks were removed to the laboratory, so that the processes could be studied as they were taking place.

TYPICAL SOILS DERIVED FROM THE DECAY OF LAVA.

Two general types of soils are recognized as the resultant of the decomposition of the lavas in the Hawaiian Islands. These are distinguished at once by their color, and the two types are known as the "dark red soils" and the "yellow soils." This distinction in color, however, does not always serve to define the types of soils themselves, as both the chemical analysis and the character of the crops produced show that the soils of the yellow color sometimes belong to the red type and the soils of red color to the yellow type. It must not be understood from the names given to the typical soils that all the soils of the islands can be readily grouped by their appearance into two classes. Between these definite types may be found all gradations of color, and a gradual merging of one type into another. In general in the islands the red soils are considered the more fertile, but, as intimated above, this is not always the case.

The dark red soils appear to have come, as a rule, from the lavas which were more or less free-flowing at the time of their ejection, and which have undergone slow disintegration, and where the rainfall has not been abundant. These soils usually are rather deep, in some places extending to a depth of three or four feet without any marked change of texture or color. The red color is so deep as to be appropriately designated "blood red." In many places where these soils have been formed large blocks of lava remain undecomposed, and are scattered over the surface of the soil in much the same way that the rounded boulders are found as the result of glacial action. Great expense is often necessary to remove these boulders in order to prepare the surface for cultivation. It is evident that this coloration of the soil is due chiefly to the oxidation of the iron contained in the original basaltic lavas from which the soils were formed. In the oxidation of the iron the first step is doubtless its conversion into ferric oxid. If this disintegration takes place at high temperatures, and in the presence of a minimum amount of water, the ferric oxid is practically free from hydrate and the color is a deep red. If, however, the oxidation takes place in the presence of an abundant supply of water, ferric hydrate may be formed, varying in color from red to yellow. It is evident that the temperature at which ferric oxid alone would be formed in the presence of steam must be rather high. It has been demonstrated by experiment that at a temperature of 200° F. in the atmosphere, ferric oxid is formed directly and no ferric hydrate is produced. It is evident, therefore, that the yellow soils, the other typical variety, have been formed in conditions of oxidation favoring a production of ferric hydrate. This is rendered the more certain from the fact that when these yellow soils are heated, and the combined water which they contain is driven off, they assume at once a red color.

Nearly allied to the dark red soils which have just been described may be mentioned the light red or crimson soils. These are essentially of the same typical character as the dark red soils, but contain a larger proportion of organic matter and a smaller quantity of lime.

YELLOW AND LIGHT RED SOILS.

The yellow and light red soils have evidently been derived chiefly, not from normal lavas, as was the case with the dark red soils, but from lavas which at the time of their ejection have been subjected to some sudden change which altered to some extent their nature. Lateral or tufa cones, as has already been remarked, are found in all parts of the islands, and the soils which have been derived from these—that is, the tufa soils—are consequently found over large areas. The tufa lavas are evidently the result of the expiring activities of large craters where the ejective force is not sufficient to drive the lavas entirely to the top of the cone, but only through the lateral fissures. The yellow soils therefore evidently have arisen chiefly from the decay of the masses of tufa lava. These originally were composed of mixed colors with very distinct shades, but by the action of water and wind and cultivation, the colors have been gradually mixed until the soils have assumed the yellow tint which gives them their characteristic name.

SEDIMENTARY SOILS.

In addition to the typical soils formed *in situ* which have been mentioned above, it is evident that sedimentary soils must be found in the valleys and other places in the islands where the original soils have been subjected to any considerable degree of translation. The sedimentary soils are usually found at low levels, and have resulted chiefly from the heavy rains in the mountains carrying the soil particles down and depositing them in the valleys. Some of the most fertile plantations of the islands are located on sedimentary soils. In some cases evidences are seen that these soils were at one time subjected to the action of the sea, showing that there have been considerable changes in level since the soil formation commenced on the islands.

DISTRIBUTION OF RAINFALL.

The rainfall in the Hawaiian Islands is extremely uneven and unevenly distributed. At Sprecklesville and Lahaina, on the island of Maui, the mean annual rainfall is only about 20 inches. Around the district of Pepeekeo the annual rainfall amounts to about 150 inches. At Olaa, on the island of Hawaii, on the windward side and at an elevation of about 2,000 feet, the rainfall for the years 1894–5 was 177 inches, while at Kailua, on the leeward side and nearer to the sea, it was only 51 inches during the same period.

RELATIVE FERTILITY OF THE SOILS.

As has already been mentioned, the dark red or blood-red soils, as a rule, are more fertile than the light red or yellow type. The sedimentary soils are almost equal in fertility to the dark red variety. The average period of cultivation of the chief agricultural regions of the islands, so far as sugar making is concerned, is twenty years. It is only about sixty years since any sugar at all was grown in the Hawaiian Islands for sale, although sugar-cane had been grown in a small way for domestic consumption for a much longer period. It was not until 1880 that any great advance was made in extending the sugar crop of the islands. In 1880 the total amount of sugar produced was only 30,000 tons. At the present time the annual production is about 250,000 tons. The productivity of the soils of the different types is clearly set forth in the following table, showing an accurate measurement of the average crop per year produced on more than 80,000 acres of land for a period of three years. The estimates were made only upon those areas upon which the typical soils were well marked.

TYPES OF SOILS.	Approximate Number of Acres.	Yield of Sugar Per Acre.
		Pounds.
Dark red soils	30,000	10,411
Yellow and light red soils	32,000	6,291
Sedimentary soils	20,000	10,301

The average number of crops of cane secured is one in two years. Although the actual time of the growing of a single crop may not be much over eighteen months, the other six months must be allowed for the time of preparing the land, planting, etc. From the above it is seen that there is very little difference in the yield of sugar obtained from the dark red and the sedimentary soils, while the yield from the yellow and light red soils is only a little over half of the other two. The character of the cane grown on the yellow or light red soils, however, is higher, the canes being richer and the juices expressed therefrom being purer. It requires, therefore, a less number of tons of cane grown on the yellow or light red soils to produce a ton of sugar than from the others. This is shown in the following table:

SOILS.	Tons of Cane Per Acre.	Purity of the Cane Juice	Tons of Sugar Per Acre.	Tons of Cane to 1 Ton of Sugar.
		Per Cent.		
Sedimentary	47·80	84·2	5·11	9·1
Yellow or light red	23·60	90·5	3·08	8·1

COMPARISON OF HAWAIIAN AND AMERICAN (CONTINENTAL) SOILS.

It is interesting to compare the soils of the islands with those of the United States. In the very first place we notice the great difference in the origin of the soils. As has already been stated, the soils of the islands are essentially the products of the disintegration of basaltic lavas. The soils of the continent, on the contrary, are the product of the disintegration of limestones and granites. In addition to this, a large portion of the continent of North America occupied by the United States is covered by drift; that is, soil which has been deposited during the Glacial Age. This drift soil has in many cases been brought from remote localities, and in other cases has resulted from the grinding of the rocks in the leveling of the hills and filling up of the valleys due to glacial action. On the American continent, therefore, we find a great variety of soils, while on the

Hawaiian Islands, the soil is essentially of a single origin. A large number of analyses of typical American continental soils has been combined in the following table to get the average figures. In comparison with these are two columns of average data obtained from the analysis of a large number of Hawaiian soils of two types, viz., lowland and upland. The relative proportions of the different ingredients in the soils are shown in the table.

Ingredients.	American (continental).	American Lowlands.	Hawaiian Uplands.
Organic and combined water	5·18	16·80	23·30
Silica (insoluble)	69·02	10·29	10·67
" (soluble)	7·39	13·39	9·90
Titanic oxid	—	5·07	5·19
Phosphoric acid	0·34	0·72	0·87
Sulfuric acid	0·07	0·18	0·13
Carbonic acid	0·04	0·20	0·03
Iron peroxid	12·56	25·15	26·17
Alumina		23·54	20·06
Lime	0·79	0·85	0·64
Magnesia	0·73	1·35	0·95
Manganese peroxid	0·27	0·12	0·15
Potash	1·53	0·65	0·71
Soda	2·11	1·34	1·28

The most striking difference in the comparison above noted is shown in the quantity of insoluble silica. American soils are made up chiefly of sand in some form of combination or as pure silica. The table shows that altogether more than 76 per cent. of our continental soils consist of silica, of which nearly 70 per cent. is insoluble and a little over 7 per cent. soluble. In striking contrast with this are the data for the Hawaiian soils, showing for the lowland type a little over 23 per cent. of silica, and for the upland nearly 20 per cent. of silica. In striking contrast, too, are the relative proportions of soluble and insoluble silica in the two soils. In the American continental soil the insoluble is almost ten times the soluble, while in the Hawaiian soils the soluble and insoluble silica exist in almost equal quantities. The silica of the

American continental soils is largely replaced by iron and alumina in the Hawaiian soils. In the latter almost 50 per cent. of the total weight of the soil consists of iron and alumina existing in about equal proportions, while in the American continental soils only about eight per cent. of the total weight is composed of iron and alumina. Hawaiian soils may therefore be regarded as iron and alumina soils, and American continental soils as silicious in their composition. As is justly observed by Dr. Maxwell, the two kinds of soil are wholly different in their nature, and therefore the conclusions from an agricultural point of view which are derived from the study of one set of these soils cannot be applied with any degree of confidence to the other. The acidic elements in American soils are largely in excess, while in Hawaiian soils the basic elements preponderate.

One important consideration is derived from a comparative study of the two soils, viz., that plants are capable of adapting themselves to types of soils radically different, provided the plant food which these soils contain is accessible. In regard to the actual plant food which is present, it may be noticed that the phosphoric acid in the Hawaiian soils is about double that in the American continental soils. Potash, on the other hand, in Hawaiian soils is less than half that in the American continental type. In organic matter, on the other hand, the Hawaiian soils have the advantage, containing from three to four times as much organic matter and combined water as are found in typical American soils.

The Hawaiian soils are essentially new; in fact, the processes of soil formation are still rapidly going on. The American continental soils, on the other hand, are old, geologically considered—as old as those of the continent of Europe or of Asia.

ZONES OF AGRICULTURAL ACTIVITY.

For the purposes of agricultural consideration the Hawaiian Islands may be divided into four zones.

The first zone comprises that portion of the land beginning at the sea level and rising to an altitude of about 1,500 feet. All of this soil which is sufficiently decomposed and of proper contour and accessible to water is suited to the growth of sugar-cane, and the sugar-cane area comprises practically the lands situated between the limits of the altitude mentioned. In some rare cases sugar-cane is grown very successfully at a higher altitude, even up to 1,900 feet, but these cases are very exceptional. About one-half of the total area under cultivation in sugar-cane is artificially irrigated; the other half of the area depends upon the natural rainfall for its moisture. The character of the sugar cane grown in the Hawaiian group is probably better than that grown in any other quarter of the earth. The tonnage per acre is very high, and the juices of the cane very rich in sugar and very pure. Yields of 8 tons of sugar per acre have been secured, and an average of 4 to 5 tons per acre is counted upon in favorable years. The limit of cultivation of sugar-cane, aside from altitude, is determined by the degree of decomposition of the soil, the contour of its surface and the supply of water, the latter being the most important factor. The practical absence of running streams on the islands renders it necessary to collect the water artificially, either by ditches on the mountain sides to collect the surface drainage during times of storm, or by wells from which water is pumped to a sufficient altitude to secure the irrigation. It is evident, therefore, that the process of irrigation is expensive, and the quantity of water available is limited.

The second zone of agricultural activity comprises those areas suitable to cultivation lying at an altitude of from 1,500 to 3,000 feet. This zone is peculiarly suited to the culture of coffee, which has lately been undertaken in a systematic way on the islands. The coffee produced on the islands is now chiefly grown on Hawaii, and from the name of the district where the coffee is cultivated it is known as Kona coffee. The coffee produced is remarkably valuable, being esteemed of a finer quality than the best Mocha or Java. While the quantity of coffee produced is not yet very great, in fact, not enough to become a commercial factor, yet where it has been exposed for sale in San Francisco it has brought a higher price by about three cents per pound than the finest coffees on the market. Many advantages to coffee culture are presented in the Hawaiian group In the first place, at the altitude mentioned, viz., 1,500 to 3,000 feet, it is found that artificial shading of the trees is not usually necessary. This, as is well known in tropical countries, especially in Nicaragua and Guatemala, is a very important factor in coffee growth. In the first attempt at growing coffee in the Hawaiian group it was thought to be necessary to secure artificial shade by planting trees of rapid growth and exuberant foliage. The coffee grown under these conditions has not been of as good quality as that grown without any shading other than that afforded by the trees themselves. In the second place, owing to the higher altitude, the precipitation in the coffee zone is sufficient to secure the growth of the trees without irrigation. Were it necessary to practice irrigation for the growth of the trees, it would be impossible to expect any large extension of coffee growing in the islands, since all the available water is now employed, practically, for the growth of sugar-cane, which is more profitable than that of coffee.

In the coffee zone are grown with considerable success the vegetables and small fruits, and even grains, necessary to the sustenance of the farmers. There are many places, also, in which cinchona, camphor and rubber trees grow with exuberance.

The zone in which vegetables, small fruits and grains grow may be called the third agricultural zone, although it overlaps in almost every place the zone suited to the growth of coffee. So these two zones, viz., that in which the coffee grows and that suited to the growth of vegetables, fruits and grains, may be considered together. The importance of the proximity of the vegetable zone to the coffee growers is at once apparent without further illustration. It requires several years to bring a coffee grove into bearing. Meanwhile the owners and workers of the grove must live. If they were compelled to purchase all their fruits, vegetables and other foods, the cost of bringing a coffee grove into bearing would be greatly increased. Therefore, it is seen that the proximity of the zone where ordinary human foods can be produced in sufficient abundance is of the highest significance in considering the development of the coffee groves of the islands.

The fourth zone, from an agricultural point of view, occupies altitudes of from 3,000 to 5,000 feet. At these altitudes, wherever the contour of the surface is sufficiently smooth and the lava rocks sufficiently decayed, is found fine pasturage, where beef cattle and other domestic grazing animals flourish. It is not generally known that on these plateaus practically all the meat which is consumed in the Hawaiian Islands is produced. It is evident that these grazing lands can be made more generally effective by introducing modern methods of stock raising, so that the supply of domestic meat can be greatly increased. From an agricultural point of view that country is destined to the greatest prosperity which has the most fertile soil, the most favorable climate, the greatest variety of productions and the best markets. In all of these respects the Hawaiian Islands are most favorably situated, and it is evident that under the beneficent influence of American control, or as a part of the great American nation, they are destined to reach a state of evolution which is only limited by the areas which can possibly be brought into cultivation.

PRINCIPAL CROPS.

The chief agricultural product of the Hawaiian Islands is sugar. From what has been said it is seen that the sugarcane grows in the greatest exuberance in the dark red soils and in the sedimentary soils near the coast. There is, perhaps, no other quarter of the globe where so large a quantity of sugar can be produced per acre as in the Hawaiian Islands. The possible crop of sugar, however, is limited by two conditions: (1) the small area of land which is suitable for sugar culture; and (2) the supply of water. In those portions of the islands where the annual rainfall is less than 35 inches, it is necessary to practice irrigation. Unfortunately the excess of water which falls on one side of the islands, where the rainfall is sometimes as high as 170 inches, cannot be utilized on the parts of the islands where the rainfall is deficient. The greatest economy, therefore, must be practiced in the use of the water, and the greatest technical skill displayed in constructing reservoirs for holding the excess which is precipitated until such time as it may be needed by the crop. It is evident that all of the land suited to agriculture cannot be devoted to sugar growing, since there is a certain limit of appropriation which must not be passed. Vegetables and fruits must be grown on the islands, since it is cheaper to produce them than it would be to import them. In addition to these, the rice and taro plants must also find a place. From a careful study of the areas which can still be brought under culture, and the quantity of water which may be made available for irrigation, it seems to me that the maximum production of sugar in the islands may be conservatively placed at 500,000 tons, a little over double the annual amount now produced. In the agricultural possibilities of the islands, therefore, it is not wise to count upon a future maximum product of more than the amount just mentioned.

It is further evident that the production of sugar is not an agricultural industry in which a poor man could profitably engage, except as a renter. The cost of bringing the lands under irrigation, and the great cost of sugar factories would prevent the poor farmer from engaging in the industry on his own account. Large capital controlling large interests is necessary to produce sugar at a minimum cost.

The planting and cultivation of sugar-cane in the islands are conducted in general as in other cane-producing countries. There are, however, some peculiar conditions connected with the industry in the islands which deserve mention. In localities where the supply of water is not abundant, as, for instance, at Sprecklesville, it has been found that it is more profitable to plant the cane freshly for each crop than to depend upon the rattoons. If the water be placed upon the rattoons after the harvesting of the crop in order to preserve their vitality the growing cane must be neglected, and if the water be used for the growing cane the rattoons must be left to die. For this reason, in the localities mentioned it is customary in nearly all cases to plant anew for each crop.

In other localities, where the supply of water is abundant, either under irrigation or by natural rainfall, the crops are left from ten to twenty years without replanting, the rattoon canes producing abundantly, and having a rich and pure juice.

As in other countries, the rattoon canes contain more fiber and woody matter than the canes grown directly from the first planting. Usually, in planting, the small canes which are left in the field and the tops of the good canes are planted. Sometimes young rattoons are cut and planted. As little as possible of the rich and mature cane is used for seed purposes.

In the older fields artificial fertilizing is carried on extensively. All kinds of fertilizers are used, some of them blindly and others with due regard for the needs of the crop. At Sprecklesville, especially, the soil is deficient in nitrogen, and nitrogenous fertilizers are about the only ones employed. For this purpose fish scrap from Alaska is used. The principal point in Alaska where this fish scrap is prepared is Killisnoo.

The manufacturing season begins at various times. In fact there is no period of the year when it is not possible to make sugar. Generally, however, the season lasts from the 1st of January to the 1st of June.

RICE AND TARO.

Rice and taro are two crops which are grown under water. The white citizens of the islands who are not native born do not well endure the work in rice and taro fields. In the islands the labor of the production of rice is left almost exclusively to the Chinese and Japanese, while the production of taro is conducted by the natives.

Rice culture is so familiar that it is not necessary to describe it in detail. It can only be practiced on level areas where large quantities of water can be secured for flooding. There is, however, an upland variety of rice which is grown with considerable success in the islands. This rice does not require submersion, but grows after the manner of an ordinary cereal. Its yield per acre, however, and its quality, are not considered equal to the rice of the lowlands grown under water. Nevertheless the rice industry is one which is capable of a considerable degree of expansion, and the product of the rice fields finds a large market at home.

The taro is a plant which is known botanically as the "Colocasia antiquorum." It is also a plant which is grown under water. The taro gardens are very small in extent, but the quantity of food which they produce is something enormous. It has been estimated that a taro patch 40 feet square, containing 1,600 square feet, will produce enough food to sustain one person for a year. The taro is a plant which resembles, in many of its properties, the sweet cassava, which grows in such abundance in this country, in Florida. The starch and other nutritive properties, however, are stored in a bulbous root, and not in roots which extend from a central stem in every direction, as is the case with the cassava plant. The taro, like the cassava, contains an acrid principle, probably, as is the case with cassava, hydrocyanic acid, which renders it unsuitable for eating in the raw or fresh state. On baking or boiling, this acrid principle, being volatile, is expelled and the baked mass is entirely free of the objectionable taste and styptic qualities of the fresh material.

In the preparation of taro the bulbous roots are cleaned and baked, usually in ovens built in the earth, the heat being furnished by hot stones, previously heated by burning wood. The baked or boiled root is beaten to a paste in a wooden trough with a pestle made of a rounded piece of lava. It is then mixed with water and allowed to stand for two or three days until fermentation has taken place. Water is added until the paste is of a given degree of consistency, and the material, after thus fermented and mixed with water, is the great national diet of the natives, and is known as "poy." Poy is made either of the one-, two- or three-finger variety, the thickest paste being eaten with one finger, the next thinner variety being eaten with two, and the thinnest paste of all being eaten with three fingers. Poy is eaten by the family out of a common bowl, into which the fingers are stuck, when with a skillful whirling movement the poy is made to adhere to the finger and is then carried to the mouth and sucked off. Poy, being a starchy material, is very fattening, and on account of the ease with which it is produced and prepared, it is the food which is preferred by the native population. The whites also, after a time, learn to like it. In the valleys where the taro is grown, the patches planted are so constructed as to receive the water from a running stream. The bottom of the pond is made of fertile clay or soil, and the native islander, by working only an hour or two a day, can keep his taro patch free of weeds. The growth of taro will probably continue, indefinitely, to be one of the great agricultural industries of the islands, supplying the natives with their chief quantity of food.

COFFEE CULTURE.

The coffee industry in the islands has, in the last few years, grown very rapidly, hundreds of thousands of young trees having been planted, and many of them are just coming into bearing. Coffee trees are first sprouted in a nursery, and after attaining a growth of one or two years are transplanted to the coffee groves. As has already been intimated, it has not been found necessary, in the Hawaiian Islands, to protect the coffee plants in the groves by planting other trees. The moderate temperatures at which the coffee groves are found do not prove injurious to the plants. This is a great advantage which the Hawaiian groves have over those in the hot tropical countries, where the planting of shade trees is an absolute necessity.

Coffee trees, when properly grown, begin to bear in the fifth or sixth year, and by the seventh year, in favorable conditions, they ought to produce enough coffee to pay for their care and the interest and other fixed charges on the plantation. After the seventh year the coffee trees should yield a profit. Unfortunately for the coffee growers, the rapid decline in price which coffee has undergone in the last few years has prevented many of the owners of orchards from making the profit which they expected.

FRUITS AND VEGETABLES.

In the uplands fruits and vegetables grow with good success in parts of all the islands. It is evident that as the population of the islands increases the production of fruits and vegetables will acquire a greater agricultural significance. Strawberries, raspberries and other small fruits are grown with excellent results, and in some localities even apples and other fruits of that class can be produced. Bananas and cocoanuts are easily grown, and afford a considerable degree of encouragement for the agriculture of the future. Already large quantities of bananas have been exported from the islands, chiefly to the San Francisco markets. Pineapples grow in great abundance, and are sources of profit to the small grower. Cattle and pigs flourish in many parts of the islands, and pigs especially are found in almost every portion, as their flesh is much prized, not only by the natives, but also by the white settlers of foreign birth. There are many cattle in the hill countries where there is good grazing and yet where the land is too rough for cultivation. At these high altitudes the grazing of cattle for the meat market will probably prove profitable.

HARDSHIPS FOR THE POOR IMMIGRANT.

I have set forth above, briefly, and yet I hope clearly, the conditions which attend the practice of agriculture in the Hawaiian Islands. It is well that the intending immigrant of small means consider carefully all the hardships which he may expect before he finally decides to migrate to our far-off Pacific possessions. If he go as a mere laborer, he will have to begin in a climate to which he is not accustomed, although it is an agreeable one, and to come in competition with the cheap labor which has already been established in that locality by the importations from China and Japan. The Hawaiian Islands are, therefore, a place which, it seems to me, the American laborer should avoid, unless he can go under contract with some of the large agricultural interests, like the large sugar factories of the islands.

For the small farmer there is more encouragement, as the growth of pigs and small fruits in the uplands, coffee on the middle hills or uplands and cattle in the grazing lands still higher, form some of the inducements for profitable labor. Nevertheless, the small farmer must act with great caution and not cast his fortunes hastily in a land so far away.

For the capitalist there are yet large opportunities of successful investment in the islands. There is still a large amount of sugar land which can be brought under cultivation, but this requires a heavy outlay of capital. There are few areas now unoccupied in sugar production in the Hawaiian Islands where the land could be properly cleared, smoothed and irrigated for less than $100 an acre. Add to this the original cost and the fixed charges of the investment, and it is seen that large capital is necessary to push forward the sugar industry in the islands. Still, I think that of the three classes of probable immigrants mentioned, viz., the laborer, the small farmer and the capitalist, the advantage certainly lies with the latter.

We have seen how crops, which for countless centuries have grown on other soils, adapt themselves without harm to the new environment to which they are subjected in the islands. Here the future years will see the garden spot of the great American people, led by fate to extend their liberties and their institutions to the islands of the Pacific. The climate will attract alike the invalid, the eager traveler, the weary seeker after rest and the immigrant. Nowhere else will the sun's rays be found so grateful, the flowers so eternal, the breezes so balmy. Men and plants thrive equally well in these dreamy regions, children of the sun and sea, where neither the heats of summer wither nor the snows of winter chill. May we not hope that the flag, emblem of our progress and our power, shall also take root in this new soil, and the blessings of liberty and progress be ever secure beneath its folds.

ELECTRICAL SECTION.

Stated Meeting, November 8, 1898.

THE STATUS OF ELECTRICAL INVENTION.

By William A. Rosenbaum.

(*Concluded from vol. cxlvi, p. 456.*)

Some of the early arc lamps gave excellent results when working singly on a circuit, but as commercial lighting was impossible on this plan, something different was required. In commercial lighting, the series connected lamps were the first used, and they were made possible by one of the great discoveries in arc lamp regulation, the "shunt" circuit. This provided for the use of two magnets, one in the main circuit for pulling the arc, and the other in the shunt circuit for keeping it of uniform length. This is known as the "differential" lamp, and has been varied in a multitude of ways, but in principle remains in use to-day. The means whereby the attractive force of the magnets is utilized, has also been variously modified. The clutch, being an important element, received special attention. One of the earliest and simplest forms was known as the "ring clutch," consisting of a metal ring encircling the upper carbon or its rod, resting at one edge on a support, while its opposite edge was raised and lowered by the differential action of the magnets. An increase of the angle would cause the ring to grip the rod, enabling the magnets to lift it, while a decrease of the angle would release and allow the rod to fall. The ring clutch is seldom seen now, but its successor is usually an eccentric device of a more complex nature.

Following the successful introduction of the series lamp came a demand for long burning lamps. This was met at first, though not successfully, by changing the shape and dimensions of the carbon electrodes into plates, disks and various other forms affording more body, but the best form and the one which enjoyed the most extended use was the double carbon lamp, in which the carbons were consumed in succession. For lamps burning on constant potential circuits, the most recent and almost universally adopted plan for long burning is the "enclosed arc" lamp, capable of continuing in operation for 100 to 150 hours. This increased life of the carbons is due to the fact that the arc is enclosed in a chamber from which the atmosphere is excluded, combustion of the carbons being thereby retarded. Alternating current lamps are now in use on constant potential circuits, but their construction does not materially differ, inventively considered, from the continuous current lamps. Focusing lamps, wherein the arc is maintained at a fixed point in space, are now in common use where it is desired to project a strong beam of light. The fixity of the arc is accomplished by feeding both carbons by mechanism operating on the same general plan as that of the series connected lamps.

Taking up incandescent lighting at the beginning of its commercial existence, and bearing in mind that this paper is treating of "invention," we scarcely find anything of importance to note beyond the production of the one form of lamp which has been in use since its origin in 1879, and the system of distribution by which it is most economically operated. It is true that many processes and methods of preparing the lamp filament, of making the bulbs, of clamping the filaments to the leading in wires, and of exhausting and sealing the bulbs, have been invented; likewise improvements in the sockets and keys, but these do not rise to the dignity of "important" inventions as herein considered. With the invention of the "three-wire" system of distribution in 1882 we can safely admit that the art of incandescent electric lighting, as we know it to-day, was substantially perfected.

Experiments have been made during the past two or three years on a system of lighting which, according to the claim of the inventor, more nearly approaches daylight than any other known system of illumination. This is the vacuum tube lighting, a modification of the Geisler tube experiment, wherein the light is created by interrupting a high tension circuit in a high vacuum. This invention, while interesting from a scientific standpoint, has not yet come into commercial use.

Under the head of electric lighting we may properly refer to the beautiful discovery of X-rays by Professor Roentgen. Notwithstanding the fact that this discovery was made known less than three years ago, it has already entered extensively into the service of man. The number of prominent inventions has not been great, attention having been directed more generally to improving the apparatus at first used. The devices for producing the rays consist of a source of high potential electricity, such as an induction coil, a high frequency circuit breaker, a condenser for accumulating and rapidly discharging electric energy, a Crookes tube and a source of current such as a battery. The devices for determining the presence of the rays are either a sensitized photographic plate or a screen covered with crystals capable of becoming fluorescent under the action of the rays. The screen itself is not of so recent origin as the contrivance in which it is mounted for convenience, and which is known as the fluoroscope, the invention of Mr. Edison.

In entering upon the subject of dynamo electric machinery and electric motors we have no difficulty in placing the credit of their origin to Michael Faraday at the date of 1831. It would be a pleasure to dwell upon the beautiful experiments of this early investigator, but time presses and we must proceed to a brief review of the discovery and invention of the salient elements.

Faraday's dynamo consisted of a copper disk rotating between the poles of a permanent magnet, with brushes located respectively at the axis and periphery of the disk.

Within a few months machines on the principle of magneto-induction had been devised, and alternating currents were produced in bobbins, which shortly after was followed by the invention of the commutator for straightening out these currents. From this time on, numerous improvements appeared by Ritchie, Saxton, Clarke, Jacobi and others, until 1848 when another "milestone" was fixed in the road of development, in the discovery that the main current could be directed around the field magnet and produce a self-exciting machine. Contemporaneously the laminated armature was invented and this, shortly after, was followed by the machine in which neither field magnet nor armature rotated, the periodic variations in the magnetic field being produced by a rotating body of soft iron; 1856 marks the origin of the Siemens shuttle wound armature, and Dr. Werner Siemens is by some given the credit of the invention of machines having electro-magnets only, in contradistinction to the prior machines using all or part permanent magnets. The shunt wound machine was the invention of Wheatstone, and dates from 1867. The question of obtaining continuous currents with less fluctuation, brought out the Paccinotti ring armature, and this paved the way for the very important invention of the Gramme ring. In 1878 Brush introduced his famous machine embodying the principle of open coil working, and about this time Hopkinson showed how greatly the performance of a dynamo was improved by improving and making more compact its magnetic circuit. In 1881 Marcel Deprez suggested that a constant potential current ought to be obtained by providing the field magnets with a second coil supplied with uniform current from an independent source. This was almost immediately followed by the adoption of the compound winding for obtaining self-regulation.

The discovery that the action of a dynamo is the simple converse of that of the motor, and that the same machine can serve either function, appears to have been gradually made. The earliest electric motors in which the principle of attraction by an electro-magnet was applied, were those of Henry, in 1831 and of Dal Negro in 1832, and these were followed by the machines of Ritchie, Jacobi and Davenport. The idea of transmitting power from one dynamo as a generator to another used as a motor, is ascribed to Fontaine and Gramme in 1873. In 1882 Ayrton and Perry made the important discovery of the automatic regulation of motors to run at constant speed, by methods the converse of those adopted for making dynamos self-regulating.

We cannot leave the subject without brief reference to the development of the polyphase motor. The birth of this piece of machinery, which is now so rapidly coming into use, is accredited to Mr. Walter Bailey, in 1879. Bailey's machine had four electro-magnets, 90° apart, facing a copper disk; the magnetism was caused to shift progressively from pole to pole, thus producing eddy currents, which by their reaction gave the disk a mechanical motion in the direction of the progression of the poles. In 1883 Deprez laid down the important theorem as to the production of a true rotating magnetic field by the combination of two alternating currents, having as their difference of phase a quarter period. In 1893, at the World's Fair, Professor Ferraris exhibited a machine embodying two pairs of electro-magnets, having a common yoke and a pivoted central body. Two alternating currents differing in phase were passed through the two-field circuits, causing the central body to rotate. Amongst the American pioneers of polyphase investigation was Chas. S. Bradley whose work dates early in 1887. He first used a Gramme ring having four radial connectors, led off at four symmetrical points to four rings, and thus obtained two alternating currents differing 90° in phase. This machine could be used as a motor.

The work done by Mr. Tesla in the four years following 1887 was in itself sufficient to have established a rotary field motor upon a solid basis. A distinguishing feature of his motor was the absence of all sliding contacts.

Other prominent workers in this field were, Wenstrom, Dobrowolsky, Brown and Hutin & Leblanc.

In taking up the subject of chemical generation of electricity, it is not with the intention of compiling anything like a complete list and description of all the combinations proposed or actually used as primary batteries. A large proportion of them are more curious than useful, and many have scarcely the merit of novelty. It is, therefore, the intention to refer briefly, as heretofore, only to those discoveries in this field which have marked the beginnings of new classes of batteries with perhaps some reference to special novelties that have not gone extensively into use.

The Voltaic battery, as the name implies, was a discovery of Volta, who noticed the twitching of the frog's legs when touched simultaneously by connected pieces of copper and iron. From this he worked out the Voltaic pile, consisting of alternating layers of two different kinds of metal, separated by bits of moistened cloth, which was the first apparatus ever designed for the production of a continuous flow of electricity.

The first constant battery was the Daniell, invented in 1836. In this cell a copper plate is immersed in a solution of copper sulphate to prevent the disengaging of hydrogen upon it. The mechanical construction of the cell involves a porous cup, inside of which is a copper element and outside a zinc element; the zinc is immersed in a solution of zinc sulphate, while the copper is in a solution of copper sulphate contained in the porous cup.

The gravity battery is a simple modification of the Daniell, designed to avoid the use of the porous cup. The zinc and copper sulphates are separated by their difference in density.

The Grove battery consists of a cylinder of zinc, immersed in dilute sulphuric acid, and a thin plate of platinum in strong nitric acid contained in a porous cup.

Following the Grove cell came the Bunson, a modification in which a block of baked carbon was substituted for platinum.

The application of bichromates as depolarizers followed shortly after the Bunson cell. The Fuller bichromate cell provides for the continuous amalgamation of the zinc, insuring minimum local action and more constant current. The Partz acid gravity battery represents an application of the gravity principle to an acid depolarizer. The copper oxide battery, invented by Lalande and Chaperon, is an example of the use of solid depolarizers, in closed circuit batteries. Mr. Edison devised a modification of this battery, known as the Edison-Lalande, in which the copper oxide is employed in the form of a compressed slab, which, with its connecting copper support, serves also as a negative plate. The chloride of silver was a very early form of cell, its elements are zinc and silver, the zinc chloride furnishing the depolarizer, is cast upon the silver element.

The batteries so far spoken of, are of the closed circuit type, and are distinguished with one exception by the use of liquid depolarizers. We now come to those batteries in which solid depolarizers are used, and which are known as the open circuit batteries, of which the Leclanche cell stands at the head of the list. The depolarizer of the Leclanche cell is manganese dioxide; it is used in the form of granules mixed with broken carbon to increase the conductivity, the negative plate is carbon packed in a porous cup with the depolarizer, while the positive element is a zinc rod and the exciting liquid salammoniac. The prism form of Leclanche cell was devised to dispense with the porous cup, but more satisfaction has been obtained from the cell in which the carbon element, in the form of a cup, is made to serve the purpose of the earthen porous cup.

The oldest exponent of batteries in which no depolarizer is used is the Smee battery. The positive plate is zinc and the negative silver with roughened surfaces, the function of which is to mechanically dislodge the hydrogen as fast as it is released at the negative plate. The Law battery is another type of this class in which reliance is placed upon large carbon surfaces to effect depolarization mechanically.

A large portion of the more recent open circuit batteries appearing, are the so-called "dry" type which contain the excitant in the form of a paste, the composition of which in most cases, is secret.

Under the head of chemical generation, we may refer to the production of electricity direct from coal, of which the battery of Dr. W. W. Jacques is the most recent and promising apparatus operating upon this principle.

About the earliest discovery in this direction was that of Becquerel, who noticed in 1885 that he could produce a current of electricity by burning carbon in contact with an electrolyte capable of supplying it with oxygen.

Considerably later than this an experiment of Jablochkoff demonstrated that a current of electricity could be generated by the action upon carbon of a solid electrolyte in a state of fusion.

Later than this, in 1882, it was suggested by J. Hubert Davies that a current of air be used as a "depolarizer." This is one of the leading features of the Jacques battery. A year later than Davies, Mr. Alexander Melville Clark conceived the idea of "fixing the oxygen of the air in a substance susceptible of forming a liquid combination, and then expending this oxygen to produce electricity by the oxidation of a suitable substance (generally carbon), and lastly reoxidizing by the oxygen of the air, the substance which serves as the vehicle." Clark's work does not appear to have met with much success.

The inventions so far mentioned, while lacking in importance from a commercial standpoint, serve to mark the beginnings of this interesting method of obtaining electricity, and in fact, with the unimportant efforts of a few other investigators, constitute the state of the art prior to the invention of Dr. Jacques, heretofore mentioned.

Dr. Jacques demonstrated the practicability of his electric furnace by a series of experiments conducted in 1891.

His theory of the basis of his invention was that "if oxygen, whether pure or diluted, as in air, be caused to combine with carbon or carbonaceous material, not directly as in the case of combustion, but through an intervening electrolyte, the potential energy of the carbon may be converted directly into electrical energy instead of into heat." The practical apparatus includes means for creating an air blast and a furnace for heating the cell.

The Jacques theory of the operation of the cell has been recently criticised, and it is now quite generally accepted that the theory of the cell, as originally enunciated, is incorrect in several particulars. However, the important point is not so much the theory of operation whereby a new result is produced, as the fact of the result itself. The Jacques battery has undoubtedly been accepted as a prominent "milestone" that will direct a future line of development.

The origin of the secondary battery can be traced back to within a few years of Volta's discovery of the primary battery, but its importance was not appreciated at a very early date. In 1842 Grove constructed his gas battery, from which a current could be obtained by the uniting of hydrogen and oxygen, which were first produced by the electrolytic decomposition of water. But it remained for Gaston Planté, in 1860, to commercially appreciate the invention he had discovered. The Planté battery contained two simple lead elements in a weak solution of sulphuric acid. The distinguishing feature of the battery was the process of "forming," to which it was subjected, in order to produce the active material on the plates. This forming process consisted in charging and discharging the battery a number of times to gradually produce a layer of peroxide on the positive plates and spungy lead on the negative plates. Following Planté's invention came a large number of improvements thereon, some of which were directed to increasing the surfaces of the lead plates, while others were designed to quicken the process of forming. The next important departure, however, was made by Faure and Brush, about 1880. They conceived the idea of accelerating the formation of the plates by applying to their surfaces a layer of chemically prepared oxide of lead, made into a thick paste, and then converting it into active material by the action of an electric current. After the passage of the current, it was found that the oxide on the positive plates was converted into peroxide of lead, while the salt on the negative plate had been reduced to porous lead. As in the case of the Planté cell, this improvement by Faure and Brush was followed by a large number of inventions, designed to improve the mechanical construction of the cell, one of the most important developments having been invented by Sellon, and which consisted in shaping cells or chambers in the plate, for the reception of the lead paste.

The lead-zinc storage cell was another type to be early developed. In this cell one of the plates was an ordinary Planté or Faure peroxide plate, while the other was a thin sheet of lead, on which a thick layer of electrolized zinc had been deposited. In this battery many of the difficulties arising from local action were eliminated; the origin of this cell is commonly attributed to Reynier.

Another type of storage cell which has been given considerable attention and practical use, is the zinc-copper alkaline cell, in which the positive element is pure copper, produced usually by electrolytic reduction from a solution of copper oxide, and compressed into blocks or plates; the negative element is zinc, while the solution is either potash or sulphuric acid.

The liquid accumulator is a curious form of storage cell, in which the electrical energy appears to be, not in the electrodes, but in the electrolyte, and in which the electrodes, which may be of metal or carbon, are removed after the charging process, and others substituted for the discharge.

In closing the subject of secondary batteries, the third method of applying the active material to the plates, in lead batteries, should be spoken of. Besides Planté's method of electrically "forming" and Faure's method of mechanically applying the active material in the form of a paste, there is a third method, which consists in depositing or plating the active material into the crevices of the plate.

To sift out and distinguish the leading inventions from the mass of work that has been done in order to bring the electric railway to its present standard of commercial success, is no easy task, the difficulty being in determining what was invention and what was mere mechanical or engineering skill. Notwithstanding the fact that a very large percentage of the street railways in this country have changed their motive power to electricity, and nearly every new road now installed utilizes electric power, it is interesting to know that the whole art of electric traction is based upon a very few leading inventions.

The very first appearance of the electric railway in the history of the world is attributed to the little circular model built by Thos. Davenport, a Green Mountain village blacksmith, in 1837. This model consisted of a car carrying a motor whose field magnet was fixed, and whose revolving armature was connected to the axle by bevel gear. The invention, like many others that followed it through the years 1850, 1855 and 1860, failed, largely because of the lack of a suitable source of electricity. This pioneer railway, as well as those of Hall, Page and other early workers, derived its propelling current from primary batteries carried on the car. The advent of the successful dynamo electric generator marked the beginning of practical railway development. Among the pioneers who took advantage of this may be mentioned Geo. F. Greene and Stephen D. Field, who contemporaneously invented the plan of connecting the electro-motor on the car with a stationary dynamo by means of conductors. This occurred just prior to 1880.

In 1882 Jos. R. Finney exhibited an electric street car, an overhead wire, a trolley fitted with grooved wheels running on this wire as a track, and connected with the car by a flexible conducting cord. The year 1884 marks the first instance of an electric car in regular operation on a street railway track in the United States, as also the reduction to practice of the conduit system, wherein the conductors are mounted upon insulators in a conduit, and connection made therewith by means of a plough extending through the slot in the conduit.

The invention of the car controller on a vehicle receiving its propelling current from a stationary source is credited by some to Greene. The invention of the speed-controller, by commutating the field of the motor or motors and the controlling box for accomplishing this, is another important invention in the art, and while the carbon brush is used on many other machines besides on traction motors, it may be mentioned here as one of the important factors in railway development.

Still another important invention is the Sprague method of mounting the motor on spring supports, to protect the gearing and allow for slight changes of relative position of the armature shaft and axle.

One of the most important developments in the electric railway and, indeed, about the last, was the slow-speed motor, the production of which, although due largely to the skill of the designer, was the subject of an invention originally. No practical machine of this sort appeared until the summer of 1890, when the Wenstrom Company, of Baltimore, brought out a very efficient and well-designed motor that possessed this valuable property of slow speed. This machine was also among the pioneers in the so-called "iron-clad" type, where the magnetic circuit completely shuts in the armature and field coils. The speed of this machine was about 400 revolutions per minute, which permitted of its armature being geared directly to the car axle without the intermediate countershaft that had been the subject of frequent objurations from every electrical man who had been in the business long enough to have gearing give out.

We have now briefly traced the leading inventions in the main branches of the science of which we are treating, and if time permitted we might go beyond and look into the history of the secondary branches of the science including electrical measuring, electro-plating, electro-therapy, electric heating and so forth, but as the purpose of the paper has been fulfilled, perhaps the writer may be pardoned if he adds a thought or two suggested by a consideration of one of the most important inventions mentioned in the course of the paper, to wit: wireless telegraphy.

Why should the "wireless" characteristic be confined to the telegraph? If the coherer responds to interruptions of the electrical waves coming through space, why cannot the density of the waves be varied and the coherer made to respond to such variations and make wireless telephony possible? Why, indeed, should we not have wireless electric lighting when Mr. Tesla has already divided the number of wires, apparently necessary, by two? And why should we not have wireless electric railroading and wireless power transmission with selective receiving apparatus for all, preventing interference? Finally, why should not the name of the discoverer of the "Hertzian waves" become the greatest among the great names identified with the history of electricity. While these questions must be left to the future for solution, the rapidity of progress in modern times in electrical research justifies the belief that ere long all of them shall have been determined in the affirmative; indeed, almost coincidently with the penning of these lines, the announcement is made that Mr. Tesla has succeeded in transmitting large amounts of electric current through the rarefied strata of air surrounding the earth.

THE FRANKLIN INSTITUTE.

Stated Meeting, November 16, 1898.

A PROCESS OF FIRE-PROOFING WOOD TO BE USED FOR THE WOODWORK OF WAR VESSELS.

BY C. J. HEXAMER, PH. D.

Since a long time chemists, engineers and others have experimented to find a suitable process of rendering combustible materials non-combustible. My own labors have extended over a number of years. In a paper "On the Prevention of Fires in Theatres," read before the Institute on June 21, 1882, I called attention to what had been accomplished to make scenery in theatres fire-proof, and gave expression to my ideas on the subject, based upon a series of laboratory experiments. A special committee of the Franklin Institute was subsequently appointed for further investigation, with myself as chairman, and, at the request of my fellow-members, I conducted a number of additional tests, the results of which were embodied in a report accepted at a stated meeting of the Institute, April 18, 1883. After the sad catastrophe, occasioned by the burning of the Central Theatre, at Philadelphia, I was requested by the Secretary of the Institute to prepare a paper, which I read at the stated meeting held May 18, 1892, in which I submitted, in a casual way, the results of further experiments—giving a *résumé* of the United States patents on "fire-proofing," and pointed out the prerequisite conditions necessary to make theatre scenery incombustible. I desired to show that anyone, with a little practice, could protect scenery without having recourse to patented processes, for some of which, I was informed by theatre proprietors, exorbitant prices were being demanded. The problem of rendering scenery incombustible has, generally speaking, been solved. All the above papers were printed in the *Journal of the Franklin Institute*, and are readily accessible. I will not, therefore, take up valuable time by repeating anything there stated.

When our recent war with Spain demonstrated *ad rem* the necessity of rendering the woodwork of war vessels incombustible, I again set to work on the problem of fire-proofing wood, not with a view of pecuniary gain, but to render my country a service.

The Secretary of the Navy has appointed a "Board for Investigating the Matter of Fire-proof Wood for Use in Naval Vessels," and early in October of this year the chemist of the Board applied to me for advice. I wrote him that my experiments had convinced me that satisfactory results could only be obtained by a process of injection and precipitation in the fibers of the wood; and later he wrote me that he had now arrived at the same conclusions. I state these facts to dispel any wrong impressions that may have arisen, for I am not appearing before you to-night to exploit a commercial enterprise.

The problem to be solved is not an easy one, and in order that the results I obtained might be corroborated by an unbiased authority—for investigators are often deceived into anticipating the favorable results they are seeking—I submitted my conclusions to the professor of chemistry at the Philadelphia High School, Dr. H. F. Keller, whose experiments have verified my results.

A process for fire-proofing the wood of war vessels must possess the following qualifications: (1) The material deposited in the fiber of the wood must render it thoroughly incombustible; (2) moisture or water, whether fresh or salt, must not affect the materials in the wood, in other words, they must be insoluble; (3) the impregnating matter must adhere permanently to the fiber so that it cannot be shaken out by any amount of wear or jarring; (4) glycerine or like hygroscopic substances, used in conjunction with other chemicals to render theatre scenery incombustible, must not be used, as they would tend to rot the wood; (5) the entire mass, not the surface only, must be equally well protected by the fire-resisting substance, because in battle the woodwork is broken and shattered, and external applications permeating the wood but a short distance, though valuable in ordinary buildings, would be useless for the former purpose.

Water is not only our cheapest solvent, but also the one universally obtainable, and therefore best suited to be used on a large scale. For this reason I concluded to employ a substance soluble in water in the primary saturating liquid, which, in turn, was to be rendered insoluble by precipitation in the fibers by an aqueous solution of another substance, forming with it an insoluble compound. Such a process, with ideal substances, would possess the additional advantage that the insoluble compound would be precipitated, as infinitesimal particles, into the very fibers of the wood, causing it to remain there permanently. No amount of jarring or vibration could shake it out, for, like a soluble dye-stuff made fast or insoluble by a mordant in textile fabrics, it would last as long as the fibers in which it is imbedded.

Injection into the fibers of the entire mass, and the precipitation there of an insoluble fire-resisting compound is, therefore, the desideratum.

The question naturally arises, how can a solution be forced into the innermost recesses of the fibers of thick masses of wood? I knew that the most reliable experimental work regarding the saturation of wood with solutions had been done in connection with various attempts to preserve it against rotting and the toredo or ship worm. Before, therefore, beginning to experiment blindly, I carefully studied what had been done in this direction; examining technical books and journals, Wagner's "Jahrbuecher," the reports of committees, boards of inquiry, state commissions, patent reports and processes in actual use.

As a result of my studies and experiments, I came to the conclusion that the best method for impregnating the entire mass of the wood was to subject it to the following process: In the first place, use only well-seasoned timber, thoroughly air- and kiln-dried, and worked approximately into the dimensions needed, or, better still, impregnate, whenever possible, the finished articles. Then place the wood into a strong metal chamber, specially made for the purpose, capable of withstanding strong pressures, supplied with a lid that closes it hermetically. The receptacle is surrounded by a steam jacket, so that the temperature in it can be regulated at will. The interior of the chamber must be thoroughly dry before the wood is placed there. Let me caution you against steaming lumber before saturating it, a custom still prevalent in many creosoting works. The laborious tests of Drude have conclusively proved that steaming wood before impregnating it with solutions tends to lessen its absorptive powers, and that, therefore, it should be as dry as possible. The temperature in the receptacle is slowly increased above the boiling point of water, which is maintained until all the moisture in the wood has been expelled and the mass is equally heated throughout. The chamber is then hermetically sealed and the temperature in it is reduced to 60° C., and held there. The air in the receptacle is now extracted as quickly as possible by means of an air pump. The more complete the vacuum the better will be the ultimate results. Few persons have any idea of the amount of air contained in porous substances like wood. I certainly had not, until I began experimenting. After the air in the wood has been removed a solution of water glass of about three times its volume of water, previously heated to 60° C., is sprayed into the vacuum. This method of injection is used to remove the air in the solution. The solution must not be too dilute, but at the same time not so thick as to refuse to enter the finest tissues of the wood; in other words, it must be of such a consistency that after impregnation it is completely retained in the pores. It is almost needless to add that the final results depend on the completeness with which the moisture, sap and air have been removed from the wood before impregnation.

I will not weary you by recounting the lengthy list of materials employed as a primary impregnating fluid, only to return at last to the one with which I had started—soluble glass, one of the best known of fire-proofing materials, which possesses the additional advantage that it is cheap.

I might state here that for ordinary purposes a block of wood can be made fire-resisting by repeatedly soaking it in a water-glass solution, and, when dry, coating it with a mixture of the liquid and cement.

To return to the process, when the wood has become saturated with the solution at normal conditions, hydrostatic pressure of about ten atmospheres is applied, which is kept up for three hours; this drives the liquid through the mass. Numerous experiments made in Germany for the conservation of wood (see Mittheilungen des technologischen Gewerbemuseums. Abtheilung, Holz) have conclusively demonstrated that the "hydrostatic-pressure method" is the only one to be relied upon for forcing solutions to the innermost parts of a log.

The question now becomes what to use to precipitate insoluble silica from the solution of soluble glass, thereby forming an insoluble compound in the fibers? A dilute solution of hydrochloric acid was tried at first, but this affected the wood, and would in practice attack metal receptacles. Gaseous and liquefied carbonic acid were experimented with, also calcium chloride, until finally a solution of ammonium chloride, a very cheap substance, was used with excellent results. This produces in the very fibers of the wood a gelatinous precipitate of silica, most suitable for our purpose; salt, which is readily removed from parts near the surface by soaking in water, tending to preserve the wood in the interior; and ammonia gas, which goes off *per se*.

To apply this secondary liquid the water-glass solution is drawn from the receptacle, and the before-described process is repeated with the ammonium chloride solution. In practice it may be found advantageous to use a second receptacle, removing the wood from one to the other. The pressure should be applied gradually in the second treatment, so as not to force out the first solution. After the precipitation has been completed the wood is thrown into a stream of running water to dissolve and wash out the salt near the surface, and is then slowly dried.

It may be of interest to add that, as a secondary result of my experiments—by using stronger solutions than are necessary for fire-proofing purposes—I had some beautiful specimens of petrifaction; and Dr. Keller so completely turned a piece of filter paper into stone, that it seemed to be a delicate film of some pure white silicious mineral, and no one could possibly have surmised what the substance originally was. It is, therefore, possible that this process can be utilized in the arts in the future to petrify organic substances.

It will probably be urged that my process is expensive; but in a case like this expense is not a factor. We cannot afford to take the risk of not having everything possible about a man-of-war—or for that matter of any ship—fire-proof, when upon that fact may depend a victory or a defeat of our navy. Nor is the expense as great as it at first appears; for the Government should attend to this work itself, and not leave it to contractors. In point of fact, I believe it will be found that the only considerable outlay necessary would be the first cost of the large air-tight receptacles. There are, no doubt, plenty of pumps on hand that could be utilized, the amount of labor required is trifling, the chemicals used are of the cheapest, and the plant can be located in a place where running water costs nothing. I therefore fail to see any possible reason why lives on ship should be endangered by fire in the future.

I beg leave to state, in conclusion, as my humble opinion, that everything on board of a ship can be made fire-proof. Some things, of course, must be excluded by necessity, such as food, fuel and ammunition.

OLD AND NEW METHODS APPLIED IN PLANNING PIPE-LINES AND PENSTOCKS.

By F. M. F. Cazin.

The author of the cited paper desires to substitute therein the last paragraph on page 291 by the following lines, and to state that the substitution will further facilitate a clear conception of the new method, but without in any way subjecting it to modification:

" It seems to be entirely superfluous to carry the demonstration any further. That which has been shown appears to be sufficient to convince us of the existence, in pipes of uniform width, of causes for loss of capacity of delivery, which causes, under the new method, find an intelligent explanation and at the same time an adequate remedy. And these causes may be specified as follows, namely:

"(1) The loss, attributed to *orifice of influx*, is caused by insufficiency of current-section for permitting more than a certain quantity of water to pass with the velocity due to the head between the level of orifice and the surface of supply. For a stated diameter of pipe the said quantity may be increased, by lowering the level of orifice, thus increasing the head above the same, and in consequence the velocity of inflow. Equivalent means for increase of quantity are extant in widening the orifice of influx, according to requirement of new method.

"(2) The loss, commonly attributed to *friction*, is caused by one of two other and real causes, or by either thereof, namely:

"*a.* The water falls in such quantity, as area of orifice and head above orifice will permit, and this quantity falls in its natural form with its naturally increasing velocities, leaving all the water in the pipe, which fills the space, not included in such natural form of flow, comparatively without motion, just so as if such excessive space were not enclosed in the pipe; or, *b.* The space in excess of the natural requirement must be successively supplied with water, causing the water to fall with a larger transverse section, and, as the falling quantity is limited by the inlet, the fall proceeds with less velocity. Excess of space is beneficial only when uniformly provided for, and when in close adaptation to the form indicated by nature and disclosed by the modern method."

NOTES AND COMMENTS.

THE X-RAYS IN METALLOGRAPHY.

The latest application of the X-rays is to the study of metallic alloys. When the alloy is composed of two metals having different transparencies to the rays, radiographs taken of thin plates show the separation of the two during solidification. As an example, it is stated that an alloy of aluminum and gold shows on solidification the segregation of a definite compound of the two metals, which separates in well-defined crystals. W.

A NEW METHOD FOR HARD-FACED ARMOR.

A new method of producing a hard-faced armor plate of uniform composition has been devised by M. Werth, manager of a large iron and steel works in France. The inventor takes advantage of the fact that by suitably controlling the process of cooling it is possible to obtain some of the newer alloys of iron and steel with nickel, cobalt and manganese in either a hard, or a malleable, condition. He contends for a plate having the same chemical composition throughout, the hardening of the face being effected by tempering.

The following details of M. Werth's procedure are abstracted from the *Iron Age:*

Ordinary carbon steel in large masses cannot be tempered satisfactorily, but when alloyed with suitable proportions of nickel, cobalt or manganese it is possible to obtain the metal in a hard state by heating it up to a bright red and allowing it to cool in the air ; whereas, if heated only to a dull red and cooled, the metal will be malleable and comparatively soft. The steel used by M. Werth is open-hearth metal, free from sulphur and phosphorus. It contains from 5 to 15 per cent. of nickel or cobalt, and from 2 to 12 per cent. of manganese ; while within certain limits silicon, chromium or tungsten, may be present without interfering with the process of tempering. In its soft state such a steel has a tensile strength of 110,000 to 140,000 pounds per square inch, and a strip 1¼ inches thick can be bent without cracking round a radius equal to its thickness. After the plate is completed it is tempered by making it part of the side or bottom of a furnace. The face next the fire becomes heated to a bright red, while by means of water or air the temperature of the back face is kept down to 800° or 900° F. To insure good results the heating is effected very gradually, the plate being put into a cold furnace ; and, by preference, gas fuel is employed in the latter. Another method of effecting the heating which is, however, only applicable to flat plates, is to immerse their front faces in a bath of red-hot lead, the temperature of which is maintained very uniform. When ready the plate is removed from the furnace and cooled at the back, until the front face has sunk down to a temperature of 800° to 900° F., when no further attention is required, though, if warped, it can now be straightened before the cooling is finished. W.

A SUBSTITUTE FOR GALVANIZING IRON AND STEEL.

Wilder's patented process for coating steel and iron consists in the use of a bath composed of zinc, tin and aluminium. This mixture, it is claimed, produces a coating on iron and steel much superior to any now known, being so firmly adherent that the sheets will stand working after it has been applied, will resist corrosion, and can be heated red hot without injury. The coating is applied by the same method as galvanizing, *i. e.*, by dipping the cleansed sheets, etc., in the melted alloy. The most approved mixture is the following composition by weight: Zinc, 84 per cent.; tin, 14 per cent , lead, 1·5 per cent.; aluminium, 0·5 per cent. W.

ELECTROPLATING ON WOOD.

If a simple method of coating wood electrically with metallic deposits of silver or copper could be devised, there should be a considerable demand for such articles for ornamental parts of various articles of furniture, mouldings, picture frames, etc. Mr. C. F. Barnes describes, in the *Electrical World*, a method which, he believes, will meet the requirements. The operation is briefly as follows: The wooden article is first saturated with copper sulphate by immersing it in a solution of that substance; then removed and thoroughly dried. It is then exposed to the action of hydrogen sulphide gas, which converts the sulphate of copper to the sulphide—which is a conductor of electricity, and also insoluble in aqueous solutions. Then the article is lightly wrapped with fine copper wire and suspended in a solution of common salt at the cathode, and a current of some density is passed. The copper sulphide is thereby speedily reduced to metallic copper, by the reducing action of the cathode products. When the reduction is supposed to be completed, say in ten minutes, the article is transferred to an ordinary copper-plating bath where a coating of copper of any desired thickness may be formed upon the surface. The copper surface may be polished or varnished, and is very adherent. For silver, the process is modified by immersing the object, after preliminary coppering, in the silver-plating bath. W.

NEW METHOD OF WATERPROOFING PAPER.

The German journal *Neueste Erfindungen*, describes the following method of making a waterproof paper: The sheet is coated on both sides with a solution consisting of 1 part gelatine, 4 parts water and 1 part glycerine. When dry, the paper is immersed in a 10 per cent. solution of formalin. After this treatment, the paper is said to become impervious even to steam.

W.

RESTORING THE ILLUMINATING POWER OF INCANDESCENT LAMP MANTLES.

Neueste Erfindungen contains an interesting account of an observation, made by Herr Franck, by which the illuminating power of the Welsbach mantles may be restored. The method was described by the author at one of the meetings of the Polytechnicher Verein in Berlin.

As is well known, the mantles decline in illuminating power after they have been in use for some time. This luminosity may be restored to a certain degree, by blowing out the mantle from the inside while they are burning, which can be accomplished with the aid of a small glass or paper tube. The President of the Society stated that he had personally tested the method and had found it effective, and, in consequence, recommendable. In order to facilitate the carrying out of the process, the German Incandescent Gaslight Company manufactures a tube, mounted in a rubber ball, which is very convenient for the purpose. W.

MANUFACTURE OF STEEL CASTINGS IN THE UNITED STATES.

Mr. Stewart Johnston read an instructive paper on this subject at the recent meeting of the American Foundrymen's Association. After giving a historical sketch of the growth and development of this branch of the metallurgic arts in the United States, and some useful hints respecting the difficulties encountered in practice and how to overcome them, he gives the following statement of the present state of the art:

"The uses to which steel castings are put are beyond enumeration, and are daily becoming more varied, although at the time of their introduction in the United States, in the seventies, their position in the commercial world was one of insignificance. Limited to a few lines, the production in first years did not annually exceed 200 tons. Steel castings now invade every field in metallurgy save the one occupied by the chilled iron roll when used for rolling finished steel, and for that purpose no steel cast substitute has ever been considered a dangerous rival. It is estimated that the annual production of steel castings in the United States is from 80,000 to 100,000 tons." W.

FIRE-HAZARD OF TALL BUILDINGS.

Cassier's Magazine calls attention in a recent impression to the practical impossibility, under present conditions, of checking a fire when it attacks the upper stories of a modern American "sky scraper," and refers to the recent destruction by fire of one of the so-called "fire-proof" office buildings in New York City as another illustration of many others that might be instanced of this fact. It is obvious that with the extravagant extension skyward of so many buildings in American cities, the difficulty of successfully protecting them against destruction by fire has very greatly increased.

On this point *Cassier's* quotes the opinion of Chief Bonner, of the New York Fire Department, to the effect that none of the modern "sky-scrapers" are fire-proof, and that once a fire gets a good start in one of the upper stories, nothing can be done but to let it burn. To fight a fire above a height of 125 feet, he holds to be utterly impossible. As the only practicable remedy for this danger, he recommends that authority be given to the building department of the city to compel owners of buildings over six stories in height to provide their own fire-fighting apparatus in the form of interior standpipes and the necessary hose and other equipments.

No reliance can be placed, he holds, on the so-called fire-proof construction of walls and floors, since this has been over and over proved fallacious. W.

MAIZE OIL—A VALUABLE PRODUCT FROM THE INDIAN CORN.

The following information from a recent Government publication may pave the way for the establishment of a profitable industry:

"In the manufacture of starch and glucose, and in some varieties of maize meal, the germ, which contains the larger percentage of oil, is extracted. From this germ a valuable oil is expressed, while the residue forms a food material as valuable in every respect as that derived by the expression of the oil from ordinary oily seeds. Maize oil is easily purified, and forms a light, amber-colored, perfectly transparent liquid, without rancidity and of a pleasant taste. It has been used to some extent as a salad oil, and doubtless will in the future be very greatly employed for that purpose. It can also be used for lubricating delicate machinery, has fine burning properties, and can be used as a lamp oil. The coarser and less pure oil makes a valuable soap. In general, it may be said that maize oil has a commercial value, gallon for gallon, quite equal to the oil derived from cotton seeds." W.

THE FUTURE OF ACETYLENE AS AN ILLUMINATING AGENT.

In a thoughtful editorial on this subject, the *Electrical World* advances the following views upon the role which acetylene may be expected to play as an illuminant in competition with gas and electricity :

"As a competitor in the illuminating field acetylene will probably be a greater rival of illuminating gas than of electric current, and it is possible that its success will be of more benefit than harm to the latter. It is the old story over again of one rival stimulating another in competition, and by means of improved service and reduced cost increasing the demand by an amount greater than its own supply. Illuminating gas, electric lighting and acetylene all have their own individual advantages which, to a certain extent, outline certain fields of application of each in which the others cannot compete. For vehicle lighting, including train lighting, and for gas distribution where but a small percentage is used for fuel, acetylene will probably show advantages over other forms of gas ; while for combined heating and lighting service from one system, illuminating gas cannot be met by either acetylene or electric current, but for isolated plant service, theatre lighting and all cases where ease of control from a distance or convenience of ignition or adaptability to special decorative effects, are of any importance, the electric current has the advantage. It cannot be met by its competitors in the qualities of safety, neatness, cleanliness, convenience and elegance." W.

ALCOHOL FROM THE BY-PRODUCTS OF COKE MANUFACTURE.

London *Industries and Iron* gives the following technical item in its current notes:

"According to Herr P. Fritzsche, the gases of coke ovens are specially suitable for the recovery of alcohol. He has gone carefully into the matter, and, on reducing to alcohol the ethane contained in the issuing gas, he found a content of 1 to 1·8 per cent. by volume, and upon studying the speed with which sulphuric acid absorbs ethane, he concluded that the absorption process is perfectly practicable, the apparatus for ethane recovery from coke-oven gases being considerably smaller than that for benzol separation. Herr Fritzsche calculates that for the production of 26·5 gallons, equal to 176 pounds of alcohol, 107 pounds of ethyl sulphate, 771 6 pounds of concentrated sulphuric acid and 1,102 pounds of water are required.

"Apropos to the above item, it may be commented that the presence of ethane in the gases of the coke ovens has been known, and that the reaction with sulphuric acid is also not new. Herr Fritzsche's merit lies in pointing out that the quantity of ethane in the issuing gases of the ovens may be sufficient to make the problem of making it a source of alcohol a commercial possibility." W.

A TEXTILE FIBER FROM PEAT.

The English Board of Trade *Journal* refers to a recent report of the French Minister at Stockholm to the effect that the manufacture of textile products from peat fiber has been introduced in Sweden. The fibers, produced from peat by a mechanical process, it is said, can be mixed in the proportion of 75 per cent. with pure wool for the manufacture of yarn similar in appearance to woollen yarn. W.

ENGLISH RULES REGULATING THE USE OF PETROLEUM OILS.

In view of the inefficiency of the State and municipal laws regulating the indiscriminate sale of dangerous oils for household use, it may be of interest to note that, notwithstanding the fact that the laws already in force are much more stringent than ours, the British Parliament has deemed it necessary to appoint a Commission to revise the existing laws in the interest of the public safety. This Commission has just made a report embodying the following conclusions:

"That the present law not being adequate for public safety, should be amended in the following particulars:

"(1) To adopt a flash point of 100° Abel closed test, as the dividing line between petroleum oil and petroleum spirit.

"(2) Legislation to control the storage, transport and sale of petroleum generally and admixtures of the same with other substances, certain heavy oils being exempted.

"(3) To provide for an efficient system of testing.

"(4) To provide for adequate supervision and administration by local authorities.

"(5) That official inquiries be made into the causes of accidents arising from the storage, transport or use of inflammable liquids.

"(6) Statutory powers to enable the Secretary of State to issue orders affecting the manufacture and sale of lamps.

"(7) To spread information among the public as to the nature of petroleum and the management of petroleum lamps." W.

TECHNOLOGY OF ALUMINUM FROM A BRITISH STANDPOINT.

At the summer meeting of the Institution of Mechanical Engineers, held at Derby, Mr. E. Ristori gave the members an account of the present state of the aluminum industry in England, and in connection therewith made some interesting comments on the applications which the pure metal and its alloys had received. From these it appears that the British practice of manufacturing the metal differed in some important features from ours—notably in the use of a different form of furnace, and in the production of a crude metal which is afterwards brought up to high grade by a refining process. The details of this last would be extremely interesting, but none are given. Some useful data were given in reference to the technology of the metal, an abstract of which follows:

Mr. Ristori stated that aluminum could be forged hot or cold, and, in comparison with other metals, it ranks third in order for malleability and sixth for ductility. Sheets have been hammered as thin as $\frac{1}{40000}$ of an inch. In turning, the edge of the tool soon becomes blunt, and the cutting speed should be high. In its purest form aluminum is very soft and not of great service in those arts in which much rigidity and strength were required. One casting alloy having a specific gravity of 2·9 is now largely used, but its composition is still kept secret. It has been found to produce remarkably clean castings which required very little machining to finish up, and takes a high polish. Another alloy contains aluminum and a small proportion of copper The two alloys particularly recommended as among the best yet made are both ternary alloys, and next to the aluminum, tungsten is the leading ingredient in each. In one of them copper is present to a small extent, and in the other nickel, and both have given astonishing results as regards strength and elongation. Samples of rolled sheets or rods made of these alloys show as much as 20 to 22 tons tensile strength per square inch, with 5 to 10 per cent. elongation in 4 inches. Aluminum bronzes are undoubtedly superior in strength, and they are especially suitable for marine engineering. Mr. Ristori gave many illustrations of the uses of aluminum, and speaking broadly, he said that the metal or one of its light alloys should, to a large extent, replace copper, tin and nickel. Its use in shipbuilding is growing rapidly on account of its great saving in weight. In some cases pure aluminum is not strong enough alone, and it is thought better to use an alloy containing about 6 per cent. of copper. This possesses a tensile strength of 14 tons per square inch, but this material is absolutely untrustworthy in sea water, owing to the rapid corrosive action set up between the two ingredients. Unfortunately this comparative failure had materially discouraged the adoption of aluminum in shipbuilding, but, eventually, when further experiments have been carried out, there is no reason why a suitable alloy should not be adopted, which, when properly used and protected from direct contact with sea water, would resist corrosion as effectually as the majority of materials now employed. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, December 21, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 21, 1898.

MR. H. R. HEYL in the chair.

Present, 85 members and visitors.

Additions to membership since last report, 38.

The resignation of Mr. Clayton W. Pike from the Committee on Science and the Arts was presented and accepted.

The following nominations were made in conformity with the By-Laws—to be voted for at the annual election to be held Wednesday, January 18, 1899:

For President	(to serve one year), ...	JOHN BIRKINBINE.
" *Vice-President*	(" three years), ...	CHAS. BULLOCK.
" *Secretary*	(" one year), ...	WM. H. WAHL.
" *Treasurer*	(" one year), ...	SAMUEL SARTAIN.
" *Auditor*	(" three years), ...	WM. H. GREENE.

For *Managers* (to serve three years).

THOS. P. CONARD,
JAMES M. DODGE,
C. LELAND HARRISON,
WASHINGTON JONES,
ISAAC NORRIS, JR.,
STACY REEVES,
FRANCIS SCHUMANN,
COLEMAN SELLERS.

For the *Committee on Science and the Arts* (to serve three years).

HUGO BILGRAM,
FRANK P. BROWN,
J. J. DEKINDER,
W. C. L. EGLIN,
A. M. GREENE, JR.,
FRED. E. IVES,
CHAS. JAMES,
ARTHUR KITSON,
WILFRED LEWIS,
EDGAR MARBURG,
EDWARD F. MOODY,
C. J. REED,
E. ALEX. SCOTT,
COLEMAN SELLERS,
H. W. SPANGLER,
WM. H. WAHL,*
F. L. GARRISON,*
W. N. JENNINGS.

To fill the unoccupied term of Clayton W. Pike, resigned, FRANCIS HEAD.

Capt. Joseph U. Crawford, Engineer of Branch Lines Pennsylvania Railroad Company, addressed the meeting on "An Engineer's Observations in Cuba. The speaker gave a *résumé* of observations made during a recent professional visit of several months, respecting the conditions at present existing on the Island, with especial reference to agricultural, industrial, engineering and transportation problems present and prospective.

Mr. Oberlin Smith, President of the Ferracute Machine Company, Bridgeton, N. J., by special request, repeated with some elaboration his communication lately given to the Mining and Metallurgical Section, describing a new minting plant designed and constructed by the company for the Chinese Government. The speaker illustrated his theme by the exhibition of lantern projections of the machinery and of the coins (the latter by the megascope); and gave an interesting account of the tribulations experienced by the representative of the company in transporting the plant several thousand miles into the interior of China and erecting it.

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*Declined.

Mr. Charles Day exhibited and gave a description of several forms of kites, including the Marvin-Hargrave box kite used by the U. S. Weather Bureau in making meteorological observations.

The Secretary, in discussing the subject, referred to the circumstance that some fifty or sixty years ago there was in existence in Philadelphia an active society called the "Philadelphia Kite Society," organized for the purpose of making use of the kite as an instrument in meteorological research. He mentioned the fact that Professor Espy, in his "Philosophy of Storms," made reference to the usefulness of the work of this society in determining the altitude of cumulus clouds. All traces of the records of this interesting organization, however, appeared to have been lost, as the most persistent inquiry had failed to reveal any clue as to their whereabouts.

The meeting passed a vote of thanks to the speakers of the evening.

The Secretary presented a communication from Dr. Joseph W. Richards, of Lehigh University, transmitting specimens of the salts of two alleged new chemical elements, "Cosmium" and "Neo-cosmium," described by Dr. Kosmann, of Charlottenburg.

The presumable new substances were separated from the rare earths, and are said to be of special value for incandescent lighting. The salts shown were cosmium nitrate and neo-cosmium nitrate.

Adjourned. WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held December 3, 1898.*]

PROF. L. F. RONDINELLA in the Chair.

The following subjects were considered:

Passed first reading:

Check Punch. Geo. O. Brosnaham, Jr., Pensacola, Fla.

Steam Trap. Antoine Heintz, Liège, Belgium.

The Omnimetre. Albert Sexton, Philadelphia.

The resignation of Mr. Clayton W. Pike was presented and accepted with the Committee's regrets. Ordered to be reported to the Institute.

W.

SECTIONS.

CHEMICAL SECTION.—*Stated Meeting*, December 20, 1898, Dr. Lee K. Frankel, President, in the chair. Dr. Henry Leffmann read a paper on "Digestive Ferments with Especial reference to the Effects of Food Preservatives."

Mr. Lyman F. Kebler read communications on "Bébées (a new yeast plant) and "Notes on Estimating Eucalyptol." The communications were freely discussed and referred for publication.

The following nominations were made for officers for the year 1899, viz.: President, Dr. Jos. W. Richards; Vice-Presidents, Dr. J. W. Williams and Lyman F. Kebler; Secretary, Waldemar Lee; Conservator, Dr. Wm. H. Wahl.

Special Meeting, December 6, 1898, Dr. Lee K. Frankel, in the chair. Prof. C. B. Cochran presented a paper on "The Detection of Foreign Fats in Butter," illustrated liberally with the aid of photo-micrographs.

Dr. Robert H. Bradbury addressed the meeting on "Reaction Velocity." Both communications were freely discussed and referred for publication.

ELECTRICAL SECTION.—*Stated Meeting*, December 13, 1898, President W. E. Harrington, in the chair.

Prof. Charles F. Marvin presented a communication on "The Kite as an Instrument in Meteorological Research." The paper was illustrated by the exhibition of a specimen of the Hargrave box-kite, as modified by the speaker, and of the automatic recording devices employed in meteorological work of this nature.

Prof. Arthur J. Rowland made a communication on "Commercial Photometers and Light Standards." The papers were referred for publication.

The following nominations for officers for 1899 were made, viz.: President, Prof. Geo. A. Hoadley, Prof. W. M. Stine; Vice-Presidents, G. U. G. Holman, S. B. Locke; Secretary, Geo. T. Eyanson; Conservator, Dr. Wahl.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, December 14, 1898, President A. E. Outerbridge, Jr., in the chair.

Prof. H. C. Mercer addressed the meeting on "Fresh Studies of Pioneer Tools," supplementing a former communication on the same subject. The speaker illustrated his remarks with the aid of lantern slides, and of numerous specimens of primitive tools used by the early settlers of Southeastern Pennsylvania. A Committee was appointed to report nominations for officers for the ensuing year.

MECHANICAL AND ENGINEERING SECTION.—*Special Meeting* for organization, December 15, 1898, Mr. James Christie was called to the chair, and made an address on the scope of the new Section, and the character of the work it was hoped to accomplish by its means.

Remarks appropriate to the purpose of the meeting were made by Dr. Coleman Sellers, Mr. Cyrus Chambers, Jr., Mr. Washington Jones, Mr. H. R. Heyl, Prof. Edgar Marburg, Mr. Coleman Sellers, Jr., Mr. S. L. Wiegand, and others.

A code of regulations, prepared by the Secretary, was read and adopted, and a Committee was appointed to report nominations for permanent officers.

The second Thursday of the month was chosen as the evening for holding the Stated Meetings of the Section. W.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE 75TH ANNIVERSARY OF THE FRANKLIN INSTITUTE.

AN ADDRESS BY THE PRESIDENT, ON THE OCCASION OF THE ANNUAL MEETING OF THE FRANKLIN INSTITUTE, HELD WEDNESDAY, JANUARY 18, 1899.

To the Members of the Institute:

In opening the proceedings of this annual meeting your attention is invited for a few moments to facts which appeal to your President as entitled to your consideration.

One hundred and ninety-three years ago yesterday the illustrious Franklin was born, and we may well honor the memory of him whose name was given to the Institute by the founders as the ideal of what should be expected of the membership.

The public life of Benjamin Franklin stamps him as one of Philadelphia's greatest citizens; nor does his record pale by comparison with those of men who have achieved prominence since Franklin passed away in ripe old age.

Can we honor his memory better than by maintaining the unselfish good work of the Institute, and by adding to its usefulness? He who carved his way from the printer boy to the renowned editor-scientist, sage and diplomat, early recognized the value of mutual helpfulness by an organization of kindred spirits. Wherever the work of the Franklin Institute is known it honors the name of Benjamin Franklin, and the wider its field of usefulness, the greater honor do we reflect upon that name.

Within a few days this Institute will have reached the age of seventy-five years, for its organization dates from February 5, 1824, and I would urge upon every member the importance of co-operating in a celebration which will cover the entire seventy-fifth year. Let us maintain a continuous celebration, characterized by concerted effort to advance the usefulness of the Institute, to extend its membership, to encourage its sectional and departmental work, and to secure an endowment such as will relieve your officers from the constant disheartening strain of attempting to carry on a great work with a restricted exchequer.

A committee, having the seventy-fifth anniversary in charge, purposes to properly recognize February 5th, but to supplement this recognition by a more formal celebration later in the year, in the hope that by this later date some or all of the above desirable arrangements will be accomplished facts. It is expected that the formal celebration will take place in connection with the exhibition, which it is the present intention of your managers to hold in the approaching autumn, in conjunction with the Philadelphia Museums.

Were the Franklin Institute to pass out of existence it would certainly be considered a public calamity, which would be regretted throughout the world. There is, fortunately, no immediate danger of such a calamity, but you are each asked to consider what you would be willing to do to prevent this, and devote your energy in that spirit to its immediate advancement. It is far better to cheer a friend in life than to be willing to shed tears and wear crape at his funeral.

The additions to the roll of membership, which the Secretary reported to you, and the subscriptions which have been received to the endowment fund, are practical evidences of interest exhibited. The rearrangement of our priceless Library and its protection, and the rehabilitation of our model collection, the increased attendance at our Schools, the excellent work being done by Sections and Committees, all point to an activity which only awaits additions of individual energy to bring to a speedy consummation our most enthusiastic hopes.

In the two years which have elapsed since you called me to the Presidency we have had much encouragement —encouragement often tempered by the stern necessity of making a limited revenue suffice to cover expenditures already reduced to the lowest practicable basis, but still encouragement, for increased interest in the membership was evidenced by some advance always in progress or under consideration.

In view of the prospect before us, may not your President ask the individual co-operation of every member to do something to make our seventy-fifth year of useful work memorable?

Recalling the conditions which existed seventy-five years ago, we have much to be proud of in the history of our Institute. At the time of its organization, the locomotive and the steamboat were novelties. A journey to Pittsburgh was a greater undertaking in the expenditure of time and physical energy than a trip to-day to Puget Sound.

The telegraph, telephone, electric railway, sewing machine, and the prevailing systems of lighting, heating and power transmission, were all unknown. Scientific agriculture and sanitary science were not yet born.

All the pig-iron made in the United States was produced with charcoal, and the annual output of the entire country was below the capacity of one of our modern blast furnaces.

These comments are only suggestive of the numerous advances which the *Journal of the Franklin Institute* has chronicled, and which have resulted in the present state of scientific and commercial progress. Each one can add to this imperfect list.

Many of the discoveries and inventions which will suggest themselves were first brought to the attention of the world in this venerable building, and for quite a number, our Committee of Science and Arts has awarded medals.

Recalling an honorable history and bearing an honored name, let us unite our energies to maintain the position which we are proud to know is accorded to the Institute among the learned societies of the world, and pave the way for a future which will prove that the Franklin Institute has been, is, and will continue to be, in touch with every advance, not in the mechanic arts, merely, but in all the practical applications of science to the arts that benefit mankind.

JOHN BIRKINBINE,
President.

CHEMICAL SECTION.

Special Meeting, December 2, 1898.

BUTTER AND BUTTER ADULTERANTS.

BY PROF. C. B. COCHRAN, M. A.,
State Normal School, West Chester, Penna.

Before butter fat can be subjected to analysis it must be separated from the non-fatty constituents of the butter. This is accomplished by melting the butter and allowing the water, curd and salt to settle. The clear melted fat is then poured from the lower layer of water and curd and filtered through a dry filter paper. The fat is then made ready for examination.

In distinguishing between the fat of butter and that of oleomargarine I have placed reliance upon the three following tests: (1) The refractive index, or reading of the butyro-refractometer. (2) The relative amount of volatile fatty acids, or Reichert number. (3) The temperature at which the fat becomes turbid when treated with an equal volume of strong acetic acid, or Valenta test. In practical work I have used either the Valenta test or the reading of the butyro-refractometer as a preliminary test, and for additional proof have made a determination of the Reichert number. I have never as yet, however, met a single case in which any one of these tests did not sharply distinguish between butter and oleomargarine. These tests are all easy of execution, and, as a consequence, the certain identification of oleomargarine is a very simple matter.

If, however, butter is adulterated with small quantities of foreign fats (5 per cent. to 10 per cent.), the detection of the adulteration becomes much more difficult, and a very thorough examination is necessary. In such cases, in addition to the three tests previously named, I have found the following methods of procedure most useful for the purpose of detecting adulteration in butter.

(4) Determination of the Iodine number. (5) The following color tests for cottonseed oil, Bechi test, Milliau test, Halphen's test, applied both to the fat and to the free fatty acids. (6) Saponification number, and (7) Microscopic examination of the sample just as received, and also of the fat crystallized from solution in amyl alcohol, or both, using polarized light in both cases.

The microscopic examination of butter will be discussed in connection with the methods for detecting renovated butter.

The following table shows the limits of variation in results usually obtained by the chemical tests previously named in case of butter, lard and cottonseed oil.

Tests.	Butter.	Lard.	Cottonseed Oil.
Reading of Zeiss Butyrorefractometer at 40° C.	40 to 44½ at 40° C.	49 to 50 at 40° C.	58 to 60 at 40° C.
Index of refraction at 40° C.	1·4524 to 1·4552 at 40° C.	1·4579 to 1·4593	1·4637 to 1·4650
Reichert number	25 to 32	1 or less	1 to 2
Insoluble fatty acids	86 to 89 per cent.	About 95·5 per cent.	About 95 5 per cent.
Saponification number	22·1 to 23 3	19·1 to 20·6	19·1 to 19·7
Iodine number	26 to 38	55 to 65	101 to 116
Valenta test	29 to 39	97 to 100	71 to 89
Bechi test	No change or slight darkening	No change or very slight darkening	Black color
Milliau test	No change or slight darkening	No change or very slight darkening	Black color
Halphen test	No change	No change	Red color
Halphen test on fatty acids	No change	No change	Red color

In case of stale lards both the Bechi and the Milliau tests give a decided darkening. The figures here given for the Valenta test are those obtained when the strongest glacial acetic acid is used. With an acid containing a small amount of water the results are different, but for comparative purposes are equally valuable.

While the results of the various tests given in the table show a wide difference between butter and the other fats, yet the variation in results obtained on different butters is so wide that an adulteration with 10 per cent. of foreign fat might readily escape detection by any single test. The following experiment illustrates this. To some butter fat obtained from cream churned in the laboratory was added enough lard to make the mixture contain 90 per cent. of butter and 10 per cent. lard. The pure butter fat and the mixed fat were both analyzed. The results of the analyses are as follows:

	Pure Butter fat.	90 per cent. Butter fat and 10 per cent. lard.
1. Refractometer reading	42 at 40° C.	43 at 40° C.
2. Saponification Equiv.	242	250·5
3. Insoluble fatty acids	88·42	88·95
4. Reichert number	29·5	26·8
5. Iodine number	34	36·6
6. Valenta test (strong glacial acetic acid)	35·5	41·

While the analysis of the two samples has furnished quite different results, the results obtained in case of the adulterated sample fall within the possible limits for pure butter, and if we consider each test separately there is little evidence of adulteration, but the combination of evidence is quite strong, especially when taken in connection with testimony that may be gained by miscroscopic examinations. If the adulteration of butter with any of the common fats or oils be carried much beyond the limits of 10 per cent. the detection of the adulteration becomes an easy matter, and in most cases the Reichert test alone would be sufficient.

This is illustrated in case of mixures of butter and lard by the investigations of F. Seiler and R. Heuss (*Chemie der Nahrungs-und Genussmittel. Neunter Jahrgang. Seite 336*). The following results were obtained by these chemists:

	Reichert number.
Pure butter	28·88
Lard	1·74
90 per cent. butter and 10 per cent. lard	24·55
80 " " 20 " "	21·78
70 " " 30 " "	21·56
60 " " 40 " "	17·38
50 " " 50 " "	13·86

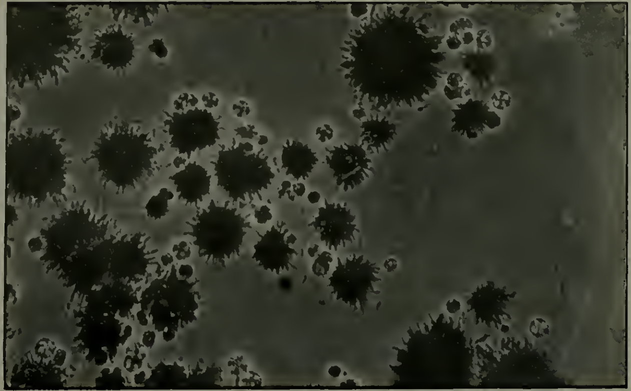
I have found the Valenta test of much assistance in detecting small amounts of lard in butter. Doubt has been thrown upon the accuracy of this test by several prominent chemists. On the other hand, it is strongly recommended by others.

Pearmain and Moor, in their little book on "Aids to the Analysis of Foods and Drugs," speak very highly of this test. From my own experience with the Valenta test, I conclude that its value has not been overestimated by the authors just mentioned.

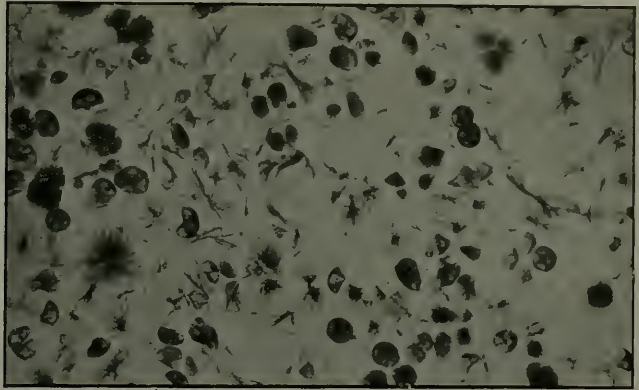
A series of tests made at the same time on different samples of fresh butter of known purity will give very uniform results. Stale butters give low results; adulterated butters usually give high results. On account of the liability of the acetic acid to lose strength by absorption of water whenever testing samples of butter of unknown origin, comparative tests should be conducted on fresh samples of known purity. If this precaution is taken I believe the results furnished by the Valenta test will prove to be very important.

The following table gives the results of the Reichert test, the Valenta test and the reading of the Zeiss butyrorefractometer on eight samples of pure butter taken from different sources, and also the results of the same tests after the addition of 10 per cent. of lard to each of the butter samples:

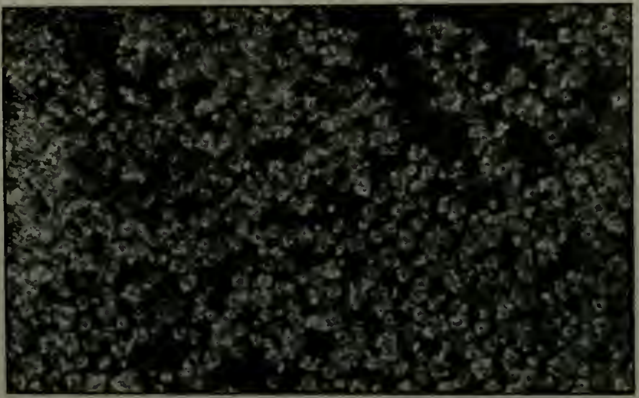
	Refractometer Reading at 40° C.	Reichert Number.	Valenta Test.	Refractometer Reading at 40° C.	Reichert Number.	Valenta Test.
	Pure Butter.			Adulterated with 10 per cent. Lard.		
(1) From West Chester Dairy	42·8	29·5	41° C.	43·2	27·	46 7° C.
(2) From a farmer	42·5	28·2	41° C.	43·	25·7	46·5° C.
(3) From Lebanon Valley Creamery	42·	28·5	41·5° C.	43·	25 6	46·5° C.
(4) From Pughtown Creamery	42·	30·2	40·1° C.	43·	27·3	46·8° C.
(5) From Faucett's Creamery	42·3	29·2	42·4° C.	43·2	25·6	47 8° C.
(6) From a creamery in Illinois	43·	29·4		44·	27·2	46° C.
(7) From Allerton Creamery	42·	31·1	40·5° C.	43·	28·	44° C.
(8) From cream churned in laboratory . .	42·	28·8	35·1° C.	43·	26·	41° C.



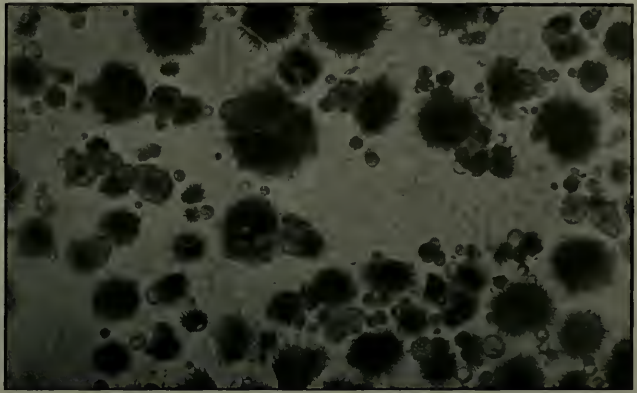
Pl. 1. Pure Butter. Cryst. from Amyl. Alcohol. x 75.



Pl. 2. Oleomargarine. Cryst. from Amyl. Alcohol. x 75.



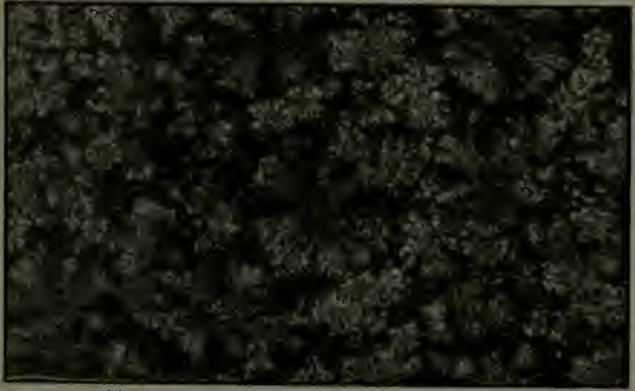
Pl. 3. Pure Lard. Cryst. from Amyl. Alcohol. x 75



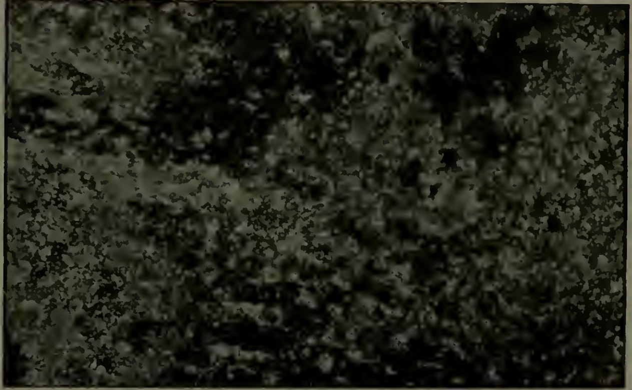
Pl. 4. 75% Butter + 25% Oleomargarine Cryst. from Amyl. Alcohol. x 75.

Pl. 5. Pure Butter. x 75.

Pl. 6. Renovated Butter. x 75.



Pl. 7. Pure Butter melted and slowly cooled x 75.



Pl 8. Oleomargarine. x 75.

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PHOTO-MICROGRAPHS OF BUTTER AND VARIOUS ADULTERANTS.

The tests on the pure butters show the following averages: Refractometer reading, 42·3; Reichert number, 29·36; Valenta test, 40·4. After the addition of 10 per cent. of lard to each sample the averages were as follows: Refractometer reading, 43·2; Reichert number, 26·55; Valenta test, 45·6. In every case but one the additions of 10 per cent. of lard has raised the results of the Valenta test decidedly above those obtained from pure butter, and this single exception is satisfactorily explained by the fact that this sample was old and very rancid when the test was made. Experience has shown me that old and rancid butters give a Valenta test much lower than fresh or well-preserved samples. In carrying out the Valenta test it should be remembered that the temperature at which turbidity is obtained depends on the strength of the acetic acid employed. In the above tests the acetic acid was 98·7 per cent. pure. With weaker acid the turbidity temperatures will all be higher, but the results will still show a marked difference between pure butter and that containing 10 per cent. of lard. A difference equally marked will be shown in the Valenta test if the butter is adulterated with oleomargarine, oleo oil, tallow or other animal fats foreign to butter.

A study was made of the mode of crystallization of fats from solution in various liquids. During the course of this work it was found that fats crystallized from solution in amyl alcohol assumed shapes very different from those obtained by crystallization from solution in ether. Judging from the results of my observations, I believe that if the conditions under which crystallization takes place are kept uniform, the crystalline deposit obtained from solution of pure butter fat in amyl alcohol will always have the same microscopic appearance, and that this appearance is characteristic of butter. This fact not only furnishes a ready method of distinguishing between butter and oleomargarine, but also some assistance in the detection of small amounts of foreign fat in butter.

On many different occasions samples of butter were adulterated with 10 per cent. to 25 per cent. of lard or oleomargarine, and attempts were made to detect this adulteration by crystallization of the fats from solution in amyl alcohol. In many cases the results of these tests were encouraging, the adulterated samples being easily identified and distinguished from the pure ones. At other times, however, no indication of the adulteration was obtained. In spite of this fact, however, the test is not without value, since it frequently furnishes very important evidence of the admixture of foreign fats. The appearance of the crystals obtained in case of butter, lard and oleomargarine, and admixture of these fats is shown in *Plates 1* to *4*.

As a result of the work done by my assistant, Mr. Brinton, and myself, I am led to the conclusion that the following tests are the most satisfactory for the purpose of detecting small amounts of foreign fats of animal origin in butter, and will usually indicate the adulteration: Direct microscopic examination of the sample by polarized light. Microscopic examination of the crystals obtained from solution in amyl alcohol both with and without polarized light. Valenta test. Reichert number. Reading of the butyrorefractometer and perhaps also the iodine and saponification numbers. The two tests last named are, however, not very promising.

EXAMINATION OF BUTTER FOR COTTONSEED OIL.

Some time ago several samples of butter were obtained in eastern Pennsylvania which had been adulterated with 3 to 5 per cent. of cottonseed oil. A considerable amount of the oil which had been used in adulterating these butters was also obtained.

The refractometer reading of the oil, obtained with a Zeiss butyrorefractometer, was 56·8 at 40° C. The iodine number was 98·5. This oil contained much cottonseed stearin, and the solidifying point was, therefore, considerably higher than that of the cottonseed salad oils (10° C. to 12° C.). It gave very strong reactions for cottonseed oil with the various color tests. At the time when these samples were obtained, a few creameries in the State were using the oil under the name of cream ripener. At these creameries the oil was added to the cream and became thoroughly incorporated with the butter during the process of churning.

In order to learn the effect of the cottonseed oil upon the quantity and character of the butter, 3 quarts of cream were divided into two exactly equal parts. One ounce of cottonseed oil was added; both parts were then set aside in a cool place until soured and then each part was churned separately. The 3 pints of pure cream yielded 16¾ ounces of butter, while the 3 pints of cream to which 1 ounce of cottonseed had been added yielded 21½ ounces of butter. This increase of weight I attribute partly to the difficulty of removing buttermilk, the butter obtained in this case being unusually hard to work.

The table on next page gives the results of several tests made on these two samples, and also of other samples of pure butter and the same butters after the addition of cottonseed oil in the proportions of 5 per cent. and 10 per cent.

The cottonseed oil used in the tests given in this table was obtained from a creamery and had been sold under the name of cream ripener. Of the various color tests for cottonseed oil, those given in the above table seem to me most reliable and best suitable for the purpose of detecting small amounts of this oil in butter. These tests are not so delicate as to give any decided reaction with the small amount of cottonseed oil which might be added with the coloring matter used to color the butter. Nor do they give a very decided reaction for cottonseed oil when applied to butter made from the milk of cows whose rations are composed in part of cottonseed meal. In the *Analyst* for October, 1898, is an article entitled "Experiments on the Effect on Butter of Feeding Cottonseed and Sesame Oil Cake," by Dr. T. E. Thorpe, F.R.S. The following statements are selected from this report:

"In a number of samples the reactions given by the tests for cottonseed oil were carefully compared with those given by similar butter fats to which 1, 2 and 5 per cent. of four representative samples of commercial cottonseed oils had been added. From a comparison of the results of the tests, it was apparent that the strongest reactions from the samples

No.	Date.	Source of Sample.	Bechi Test.	Milliau Test.	Halphen Test.	Halphen Test on Fatty Acids.	Refractometer at 40° C.	Reichert Number	Iodine Number.
1	8-24-97	Made in laboratory from 3 pints of cream	No change	No change	No change	No change	44	—	34
2	8-24-97	From 3 pints of cream + 1 oz. cottonseed oil	Darkens	Darkens	Turns red	Turns red	45·2	—	38
3	1 11-98	West Chester Creamery	No change	No change	No change	No change	42·4	—	34
4	1-11-98	West Chester Creamery + 5 p. c. cottonseed oil	Darkens	Darkens	Turns red	Turns red	—	—	—
5	1-11-98	West Chester Creamery + 10 p. c. cottonseed oil	Blackens	Blackens	Turns very red	Turns very red	44	—	—
6	2-18-98	West Chester Creamery	No change	—	No change	—	43	29·5	34
7	2-18-98	West Chester Creamery + 5 p. c. cottonseed oil	Darkens	—	Turns red	—	43·5	27·5	37·1
8	2-18-98	West Chester Creamery + 10 p. c. cottonseed oil	Blackens	—	Turns red	—	44	26 6	41
9	2-18-98	From a farmer	No change	—	No change	—	42·5	—	—
10	2-18-98	Farmer's butter + 5 p. c. cottonseed oil	Darkens	—	Turns red	—	43	—	—
11	2-18-98	Farmer's butter + 10 p. c. cottonseed oil	Blackens	—	Turns red	—	—	—	—
12	2-18-98	Lebanon Valley Creamery	No change	—	No change	—	42	—	—
13	2-18-98	Lebanon Valley Creamery + 5 p. c cottonseed oil	Darkens	—	Turns red	—	43	—	—
14	2-18-98	Lebanon Valley Creamery + 10 p. c. cottonseed oil	Blackens	—	Turns red	—	44	—	—
15	3 5-98	Faucett's Creamery	No change	No change	No change	No change	42	—	—
16	3-5-98	Faucett's Creamery + 5 p c cottonseed oil	Darkens	Darkens	Turns red	Turns red	—	—	—
17	3-5-98	Faucett's Creamery + 10 p. c. cottonseed oil	Blackens	Blackens	Red	Red	43·5	—	—
18	3-7-98	Pughtown Creamery	Very slight darkening	—	No change	—	42	—	—
19	3-7-98	Pughtown Creamery + 5 p. c. cottonseed oil	Decided darkening	—	Red	—	43	—	—
20	3-7-98	Pughtown Creamery + 10 p. c. cottonseed oil	Blackens	—	Red	—	44	—	—

from the cows fed on cottonseed cake did not much exceed that given by 1 per cent. of cottonseed oil added to butter, and the great majority of the samples gave reactions indicating less than 1 per cent.—reactions which would indeed be almost obscured in butter prepared and colored in the ordinary manner."

"The reactions vary in intensity in individual cows, but do not in any case much exceed those given by 1 per cent. of cottonseed oil mixed in butter. The presumption is, therefore, that in butter made in the ordinary way from the mixed milk of several cows, the reaction would, as a rule, be less than that due to the presence of 1 per cent. of the oil, and experiment shows that this is actually the case."

Having made an extended series of color tests on pure butter, and also on butters containing 5 per cent. and 10 per cent. of cottonseed oil, I am led to the conclusion that 5 per cent. of this oil will give reaction so strong that its presence cannot be due to the feeding of cottonseed or to the introduction of cottonseed oil used as a solvent for the coloring matter used in coloring the butter.

Several samples of butter suspected of containing "cream ripener" have been submitted to me for analysis. The following is the report of the analysis of the sample which seemed to contain the greatest amount of cottonseed oil:

Number of sample	746
Butyrorefractometer reading	45 at 40° C.
Butyrorefractometer reading of fatty acids	28 at 50° C.
Reichert number	27·2
Iodine number	44·2
Sp. gr. at 100° C. (water at 100° C.)	·90064
Melting point	39° C.
Melting of fat acids	39·8° C.

Bechi test gives dark color.

Millau test gives dark color.

*Carbon bisulphid test on fat gives red color, on fatty acids also gives a red color.

The combined results of these tests furnish convincing proof of the adulteration of this sample. The amount pres-

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* A number of water-color plates were shown, representing the results of the color tests on pure butter, on samples of butter containing 1 per cent., 5 per cent. and 10 per cent. of cottonseed oil, on cottonseed oil, and on sample No. 746.

ent in this sample seems to be about 10 per cent. Three other samples which were reported as containing cottonseed oil, gave iodine numbers varying from 41·4 to 41·1; Reichert numbers from 27·5 to 28; and refractometer readings from 44·2 to 44·9 at 40° C. The color reactions were very marked in all these samples.

RENOVATED OR PROCESS BUTTER.

This butter is made by melting stale and unmarketable butter and separating the curd and water from the clear butter oil. This butter oil is then emulsified with milk or buttermilk and again made into butter. The details of the process are said to differ greatly in the different factories. So far as I have seen, however, the process of churning is entirely omitted. The melted and emulsified fat is simply congealed by contact with ice.

There seems to be no reasonable objection to the sale of this butter when sold for what it is, but it frequently, if not usually, appears on our markets under the name of fresh creamery butter. When sold under the latter name it commands a price which the majority of consumers would be very unwilling to pay if they knew the character of the article which they were buying.

To distinguish renovated butter from creamery butter the following tests will be found valuable:

(1) Microscopic examination of the sample by means of polarized light, both with and without a selenite plate.

(2) Valenta test.

(3) The Jean modification of the Valenta test.

(4) Determination of the free fatty acids.

(5) Reichert number.

The fat of renovated butter has a more or less crystalline structure, while the fat of pure fresh butter is devoid of any such appearance. If pure butter be examined microscopically with polarized light and selenite plate, the field will be uniformly colored in any position of the analyzer, while renovated butter will show a mottled, many-colored field. Without the selenite plate and with the analyzer in proper position, pure butter shows a dark field of almost uniform appearance. Renovated butter, under similar conditions, gives a dark field, mottled with white patches. *Plate 5* shows the microscopic appearance of pure butter by polarized light. *Plate 6* shows the appearance of renovated butter under the same conditions of light and magnifying power. The peculiar appearance of renovated butter as seen by polarized light, is due to the fact that the fat has been melted, and in cooling has assumed a partially crystalline structure.

The completeness with which crystallization from fusion occurs and the size of the crystals depends on the slowness with which the melted substance cools to its solidifying point. The slower this change of temperature takes place the more perfect will the crystallization be. In renovated butter, on account of the great rapidity with which the melted fat is solidified, we get only an incipient crystallization.

If butter is melted and then allowed to cool slowly, large crystalline masses are formed, globular in shape and showing a distinct cross by polarized light. *Plate 7* shows the microscopic appearance by polarized light of butter that has been melted and allowed to cool slowly. It is needless to say that this structure bears no resemblance to renovated butter.

The microscopic appearance of renovated butter is probably not conclusive evidence of its character, as a similar appearance may be shown in old butter or in butter that has undergone alternations of softening and hardening by being exposed to temperature changes. In butter that had been rendered very soft and then slowly hardened, I have observed a field of variegated color with polarized light and the selenite plate, but without the selenite plate, I have failed to obtain the distinct white patches that I have frequently seen in samples of renovated butter.

It is my opinion that butter does not very readily, under ordinary methods of treatment, assume a crystalline condition like that shown in renovated butter, and I am, therefore, inclined to attach considerable importance to the evidence obtained from microscopic examination.

Oleomargarine possesses a crystalline structure much more marked than that shown by renovated butter. *Plate 8* shows the microscopic appearance of oleomargarine. Microscopic examination by polarized light furnishes valuable assistance in distinguishing fresh butter from old butter, renovated butter, butter substitutes or butter adulterated with fats that have been previously melted. Oleomargarine is composed of fats that have been melted and the decidedly crystalline structure resulting from this fact is shown in the illustration.

The microscopic examination of butter and its adulterants by polarized light is very fully discussed in Part First, Bulletin No. 13, U. S. Department of Agriculture, Division of Chemistry, published in 1887. Since that time the subject has been quite generally ignored by chemists, because chemical methods have been found to be more conclusive and more satisfactory. Since the advent of renovated butter upon our markets and the occasional finding of samples adulterated with small amounts of foreign fats, the subject of examination of butters by microscopical methods will doubtless receive more attention.

In renovated butters the turbidity temperature, as shown by the Valenta test, is lower than that usually found in fresh butter, and in the Jean modification of the Valenta test a greater amount of acetic acid is dissolved by fresh butter fat. Renovated butters also usually contain a high percentage of free fatty acids.

The following table shows results of examination of three samples renovated butter, and, for comparison, the results of the same tests are given on a sample of fresh butter:

No.	Sample.	Microscopic Appearance.	Turbidity Temperature Valenta Test.	Per Cent. of Acetic Acid Dissolved.	C. C. of Normal Alkali to Neutralize 100 gm. Fat.
(1)	. Fresh butter	not crystalline	60° C.	70	1·1
(2)	. Renovated butter	crystalline	48·5° C.	100	6·5
(3)	. " "	"	50° C.	100	9·4
(4)	. " "	"	49° C.	100	8·1

Sample 4 was known to be renovated butter. Samples 2 and 3, judging from analysis, I regard as also renovated butters.

Dr. Frankel, in discussing Professor Cochran's paper, stated that the subject was one of extreme importance. In Pennsylvania the sale of oleomargarine was prohibited, and, as a result, this compound and other mixtures of fats were constantly being sold as pure butter. Dr. Frankel stated that the tests used by Professor Cochran for the detection of cottonseed oil had given him satisfactory results. In reference to the use of this oil for "Butter Ripener," the results obtained on a large scale did not agree with those obtained by Professor Cochran, since there was no appreciable increase in the yield of butter. Dr. Frankel attributed this to the fact that relatively smaller quantities of cottonseed oil had been used by the manufacturer than were used by Professor Cochran.

In conclusion, Dr. Frankel stated that the microscopic examination of butter and butter compounds obtained from solutions of amyl alcohol, which Professor Cochran had made, were of interest, and hoped that subsequent work would enable the latter to work out a plan of analysis by this method.

Stated Meeting, December 20, 1898.

DIGESTIVE FERMENTS WITH ESPECIAL REFERENCE TO THE EFFECTS OF FOOD PRESERVATIVES.

By Henry Leffmann, Member of the Institute.

In strict definition an enzym or digestive ferment is a non-living nitrogenous organic body, which has the power to transform other organic bodies without losing its own identity or exhausting its functions. In the cases that have been most thoroughly studied, one or more molecules of water are condensed in the reactions and the process is called hydrolysis. It is this phase of enzym action that I will discuss to-night. A few enzyms are now known, and the study of biologic chemistry indicates the existence of many others. Indeed, it is not unlikely that the entire series of phenomena that we designate collectively as "life" is governed by hydrolytic or closely analogous changes. Enzyms, themselves, have some of the characteristics of living organisms. They are restrained in their action by apparently slight influences, may recover when these influences are withdrawn or may be injured beyond recovery. When thus "killed," as we may call it, they are not seemingly decomposed, but have simply lost an activity that they once possessed. They do not multiply, and have no particulate existence, hence cannot be classed as living organisms. They seem, indeed, to stand as the connecting link between living and non-living matter, but I need not enter into this question here.

We find evidence of a belief at an early period in the existence of so-called ferments, even in inorganic chemistry. Some of the ancient metallurgists thought that the precious metals might be obtained by mingling a fermenting or converting substance with the baser material, and in modern chemistry we see some common instances. Thus, a minute amount of iodin will convert a mass of common phosphorus into red phosphorus. It has been stated on good authority that a perfectly dry mixture of carbon monoxid and oxygen will not explode by the action of an electric spark, but if a trace of water be present, the whole mixture is at once fired. The influence of manganese oxid or ferric oxid upon potassium chlorate is a familiar instance of a quasi-ferment action.

True hydrolysis, however, belongs to the domain of organic chemistry, and is the change which determines the liberation of the potential of various food articles or renders such food articles diffusible. In most cases the reactions are too little understood in detail to be represented in symbols. In no case can we indicate the exact formation of the enzym; indeed, it is not yet sure that any enzym has been obtained in the pure state.

Obviously a study of enzyms has an important bearing upon the chemistry of digestion. Our laboratory methods are, however, such imperfect imitations of natural methods, that we must be careful how we draw inferences from results obtained in test-tubes or flasks. Many conditions obtain in natural digestion which we can imitate only imperfectly or not at all in the laboratory. There are, for example, the kneading motion, the influence of nerve supply and the constant removal of the products of digestion by osmose.

Studies of the action of various enzyms have been made by many observers. My own experiments have been chiefly with regard to the interfering action of certain food preservatives especially on starch digestion. The food preservatives commonly used are salicylic acid, sodium benzoate, boric acid, borax, sodium fluorid, sodium silico fluorid and formaldehyde.

The experiments on starch digestion were made as far as possible under uniform conditions. A starch solution, 10 grams to the liter, was made fresh each day by the usual method. Arrow-root starch, which is especially adapted to such investigations, was generally used.

The first series of experiments was qualitative only; that is, the amount of sugar or dextrin formed was not determined, but merely the presence or absence of starch, and whether the dextrin was in its fully developed condition or only in the initial stages. These facts are determined by a solution of iodin and potassium iodid in water. This produces a red color with the dextrin first formed, a pale yellow with the fully formed dextrin, and a greenish tint with very small amounts of starch. These tests are preliminary only. Much more information is obtained by determining the amount of sugar formed, and this was done in a number of cases, as will be noted. Many experiments that are in the laboratory record are not reported, being merely duplicates or vitiated by some accidental error. All weights are in milligrams. Short tests (*e. g.*, one hour) were made at about blood heat; when the liquids were allowed to stand over night, it was at room temperature. The commercial form of the antiseptic was used unless otherwise specified. The enzyms were all in good condition. The following is a description of the enzyms used :

(1) *Malt Diastase.*—An active form obtained from Merck & Co.

(2) *Taka-diastase.*—The recently introduced enzym; an active starch-transforming agent. It was used both in the powdered form and in active solution. Both preparations were from Parke, Davis & Co.

(3) *Pancreatic Extract.*—A solution prepared by Parke, Davis & Co.

(3) *Peptenzyme.*—A preparation in form of powder, made by Read & Carnrick, and containing all the digestive enzyms of the alimentary tract.

(5) *Carase.*—The enzym of the papaw; the preparation used was that sold under the trade-name "caroid."

Some experiments were made with the pine-apple ferment and also with pepsin, but the results are not worth reporting.

Antiseptic.		Taka-Diastase.	Results.
None	—	11	Starch all converted.
Saccharin	10	11	Some starch present.
Saccharin	50	11	Much starch present.
		Carase.	
None	—	20	Starch all converted.
Saccharin	10	20	Much starch present.
		Peptenzyme.	
None	—	20	Starch all converted.
Saccharin	50	20	Much starch present.
Beta-naphthol	10	20	Starch all converted.
		Taka-Diastase.	
Beta-naphthol	10	11	Starch all converted.
Formalin	3 c.c.	11	Starch all converted.
		Pancreatic Solution.	
Formalin	1 c.c.	1 c.c.	Much starch present.
		Taka-Diastase.	
None	—	10	Starch all converted.
Artificial benzoic acid	100	10	Faint trace of starch.
Artificial benzoic acid	50	10	Starch all converted.
Natural benzoic acid	100	10	Starch all converted.
Artificial sodium benzoate	100	11	Starch all converted.
		Malt Diastase.	
Benzoic acid	100	20	Much starch present.
Benzoic acid	50	20	Starch all converted.
Sodium benzoate	100	20	Starch all converted.
Boroglycide	3 c.c.	20	Starch all converted.

Pancreatic Solution.

None	—	3 c.c.	Starch all converted.
Salicylic acid	50	3 c.c.	Much starch present.
Benzoic acid	50	3 c.c.	Much starch present.
Benzoic acid	10	3 c.c.	Starch all converted.
Sodium benzoate	100	3 c.c.	Starch all converted.
Sodium carbonate	—	3 c.c.	Much starch present.
Citric acid	—	3 c.c.	Much starch present.

Carase.

Salicylic acid	10	30	Much starch present.
Benzoic acid	100	30	Starch all converted.
Sodium benzoate	100	30	Starch all converted.
Boroglycide	0·5 c.c.	30	Much starch present.

Taka-Diastase.

Boric acid	200	11	Starch all converted.
Boric acid	100	11	Starch all converted.
Boric acid	50	11	Starch all converted.
Borax	200	11	Starch present.
Borax	50	11	Trace of starch present.
Boroglycide	3 c.c.	11	Starch all converted.
Tartaric acid	25	11	Some starch present.
Citric acid	100	11	Much starch present.
Citric acid	25	11	Starch all converted.

Malt Diastase.

Borax	50	—	Much starch remaining.
Borax	25	—	
Boric acid	25	—	Much starch remaining.
Borax	25	—	

Taka-Diastase.

Boric acid	25	—	Starch all converted.
Boric acid	50	—	

Pancreatic Solution.

Borax	50	—	Starch all converted.

Peptenzyme.

None	—	—	Trace of starch present.
Boric acid	25	—	
Borax	25	—	Much starch present.
Boric acid	20	20	Starch still present.
Borax	20	20	Starch still present.

Pancreatic Solution.

Boric acid	100	1 c.c.	Very faint trace of starch.
Boric acid	20	1 c.c.	None.
Borax	100	1 c.c.	None.
Borax	20	1 c.c.	None.
None	—	1 c.c.	Starch all converted.

		Carase.	
Boric acid	100	20	Starch present.
Boric acid	50	20	Starch converted.
Borax	10	20	Starch present.
Boric acid and borax, each	25	20	Starch present.
Boric acid and borax, each	10	20	Starch all converted.
None	—	20	Starch all converted.
Sodium silicofluorid	10	20	Trace of starch present.
Sodium silicofluorid	50	20	Much starch present.
		Malt Diastase.	
Sodium fluorid	100	20	Starch all converted.
Sodium silicofluorid	100	20	Starch all converted.
		Taka-Diastase.	
Sodium fluorid	25	11	Starch all converted.
Sodium silicofluorid	25	11	Starch all converted.
		Pancreatic Solution.	
Sodium fluorid	10	1 c.c.	Solution rendered perfectly clear, but starch not converted.
Sodium silicofluorid	25	1 c.c.	Starch solution remains cloudy.

EXPERIMENTS TO DETERMINE AMOUNT OF SUGAR FORMED.

Starch solution, 10 grams to 1 liter, 50 cubic centimeters used in each experiment, all solutions diluted to 150 after digestion.

(1) Salicylic acid	50	Taka-diastase	11
(2) Sodium benzoate	50	Taka-diastase	11
(3) Saccharin	50	Taka-diastase	11
(4) Boric acid	50	Taka-diastase	11
(5) No antiseptic	50	Taka-diastase	11

(1) Shows starch reaction strongly and only traces of sugar; 133 cubic centimeters of the solution do not reduce 10 cubic centimeters of copper solution equivalent to 0·046 dextrose.

(2) No starch present; much sugar formed.

(3) Much starch present; traces of sugar.

(4) No starch present; much sugar formed.

(5) No starch present; much sugar formed.

		Pancreatic Solution.	
(6) Salicylic acid	50	1 c.c.	No sugar formed.
(7) Sodium benzoate	50	1 c.c.	Much sugar formed.
(8) Saccharin	50	1 c.c.	No sugar formed.
(9) Boric acid	50	1 c.c.	Much sugar formed.
(10) None	—	1 c.c.	Much sugar formed.

Measured by Fehling's solution volumetrically, Nos. 7, 9 and 10 showed the same amount of sugar.

		Pancreatic Solution.	
(11) Salicylic acid . . .	50	3 c.c.	No sugar formed.
(12) Sodium benzoate . .	50	3 c.c.	Much sugar formed.
(13) Saccharin	50	3 c.c.	Trace of sugar formed.
(14) Boric acid	50	3 c c.	Much sugar formed.
(15) None	—	3 c.c.	Much sugar formed.

Tested by Fehling's solution, Nos. 12, 14 and 15 showed the same quantities of sugar; no starch was present. Starch was abundantly present in Nos. 11 and 13; in the latter it was well liquefied, but not in the former.

EXPERIMENTS UPON DIGESTION OF PROTEIDS.

The information on this phase of the question is still very incomplete. The products of proteid digestion are much more complex than those of starch digestion, and the detection and estimation of the different substances are much more difficult. The action of pepsin is peculiar in that it requires a distinct amount of acid. Pancreatic digestion, on the other hand, is promoted by alkalies and is restrained by acids. Chittenden found that even after two weeks' continuous action of a mixture of hydrochloric acid and pepsin made in close imitation of human gastric juice, only a little more than half of the proteid was converted in peptone; that is, had been fully digested.

The general conclusions that may be drawn are:

Salicylic acid in all its forms, *i. e.*, natural, crude commercial and refined commercial, is distinctly antagonistic to most enzyms, especially those that convert starch. There seems to be no reason to believe that the natural form of the acid will be less objectionable than the artificial in this respect, even if its price does not exclude its use.

Sodium benzoate is without appreciable interfering action, and as its preservative action is undoubted and its disagreeable taste will prevent its liberal use in any food article, it seems to be well adapted for general use.

Boric acid and borax show but little interfering action with either starch or proteid digestion. Boroglycide seems also to possess but little interfering action.

Beta-naphthol interferes with the action of malt-diastase, but not seriously with taka-diastase or pancreatic extract.

It interferes very decidedly with peptic and pancreatic digestion of proteids.

Sodium fluorid has but little interfering action with starch transformations, but sodium silicofluorid interferes decidedly with pancreatic extract.

Salicylic acid does not interfere seriously with proteid digestion.

Concerning the effects produced upon the human system by long continued administration of small doses of common food preservatives, we have, as remarked above, but little information. Some German investigators have studied the action of salicylic acid in this respect, notably Kolbe, who discovered the synthetic method of preparing it. He found no appreciable injurious effect, but he probably used a purer article than is often found in commerce. Experiments on lower animals are numerous. Among the most recent of these is a contribution by R. A. Chittenden and W. O. Gies, of Yale University (*Amer. Jour. of Phys.*, Vol. I, No. 1), detailing an extended study of boric acid and borax on the nutritive and excretive functions of dogs. All the data are given in the report, and great care was taken in the experiments. Among the conclusions are the following:

Moderate doses of borax, up to 5 grams per day, even when continued for some time, are without influence upon proteid metabolism, and do not exert any specific nutritional changes. Under no circumstances, so far as we have been able to ascertain, does borax tend to increase body weight or to protect the proteid matter of the tissues.

Boric acid in doses up to 3 grams per day is practically without influence upon proteid metabolism and upon the general nutrition of the body.

Borax, when taken in large doses, tends to retard the assimilation of proteid and fatty foods, increasing notably the weight of the feces and their content of nitrogen and fat. With very large doses there is a tendency toward diarrhœa, an increased excretion of mucus. Boric acid, on the contrary, in doses up to 5 grams per day, is wholly without influence in these directions.

Both borax and boric acid are rapidly eliminated from the body through the urine, twenty-four to thirty-six hours being generally sufficient for their complete removal.

In this connection I wish to read an extract from an English journal, *Food and Sanitation*, which, although representing, of course, the English point of view and methods, yet is largely applicable to the situation everywhere, and expresses, to a great extent, my own views:

"Ever since the advent of the Food and Drugs Act difficulties have arisen as to the interpretation that should be put upon certain clauses, and, despite numerous amendments, many of these difficulties still pertain.

"Of late a new phase of the question has predominated, in that attention has been directed not only to actual adulterants, but substances which are used as preservatives.

"It appears that Dr. Hill, the Birmingham Medical Officer of Health, has arrived at the conclusion that the use of chemical preservatives ought to be prohibited altogether, because they enable foods to be sold as fresh which are stale, and which have undergone such putrefactive changes as to make them frequently harmful, and sometimes actually poisonous. Secondly, whatever minor differences may exist among physiologists, Dr. Hill contends that they are agreed upon one thing, namely, that even though small doses exert apparently no serious influence upon health, the same could not be said of large doses. In short, all additions to food whose influence on health was doubtful, ought to be prohibited, and their use supplanted by refrigeration.

"These are pronouncements which involve many issues, and raise more difficulties than are apparent to the mental eye at the first glance.

"It is hard to know where we are to stop in defining what shall come under the heading of 'doubtful additions' to food. Take, for instance, boric acid in butter and saltpeter in curing hams and pickling beef.

"Niter is as much a chemical or a medicine as boric acid, but it has been used for too many years as a food preservative, to be displaced summarily. Yet if boric acid and the etceteras are to go, so must niter.

"What is more, while refrigeration is an excellent alternative in the abstract, it does not lend itself to local requirements, to say nothing of the expense. It may be a simple thing to enforce refrigeration and forbid the use of 'preservatives' by law, but even when a certain line of action is actually legalized, it does not follow that it is expedient.

"There is something rather too utopian about the whole idea of thus banishing from use all food ingredients that may in any possible way injure health. What will harm one will not affect another."

It seems to me that a wholesale prohibition of the use of preservatives will work much wrong. Food in an incipient state of decomposition will do bodily harm, and there is a new field for preservatives for many forms of food. I think they should be rigidly excluded from milk, because that is a food intended to be used fresh, or, if not, the sterilization of it will accomplish the needed preservation.

In permitting the use of preservatives we should endeavor to secure those which show the least interference with digestion and the least tendency to disturb the nutritive functions. From the facts at hand I believe that boric acid and sodium benzoate are most suitable from these points of view. In judging between them I would be guided by the fact that the latter contains no mineral substance foreign to the human system, and that it is essentially organic in its nature, and hence more likely to be eliminated promptly. It seems that boric acid has little disturbing effect, but the fact that it is a mineral substance not normal to the tissues is somewhat against it.

DISCUSSION.

MR. KEBLER:—In this paper the idea is expressed that a given amount of enzym will convert an infinite amount of material. That enzyms do bring about changes apparently incommensurably great, compared with the amount of enzym employed, is true, yet the results of modern research point to the fact that they do "wear out." Perhaps all enzyms, in the course of their activities, produce bodies which slow and by accumulation, ultimately stop the reaction long before the enzym is exhausted or is destroyed, but would the absolute removal of these bodies prolong their activities infinitely?

Dr. Leffmann:—No experiments are at hand to prove that enzyms are inexhaustible, but it seems probable that if we could remove the products of the action and add new materials without further diluting the liquid, the enzym would maintain its efficiency. We have, for example, O'Sullivan's statement that he found that one part of invertase would invert 100,000 times its weight of cane-sugar and still be active. In the inorganic world we know that one grain of manganese dioxid might suffice to assist the decomposition of an indefinite amount of potassium chlorate and not lose its efficiency.

Mr. Kebler:—In reference to the presence or absence of free benzoic acid in such substances as pickles and catsups, when sodium benzoate is employed as a preservative, there seems to be some difference of opinion. I have always been of the opinion that the acid of the pickling medium liberates the acid from the sodium benzoate and the benzoic acid then became the preservative. Experienced men in this art hold similar views. Some practical men have told me that they use the sodium benzoate rather than the benzoic acid itself, because the former dissolves readily and can thus be easily and uniformly distributed in the things to be preserved.

Dr. Leffmann:—In many foods benzoic acid will be set free, but I think not in all.

Dr. Frankel, in discussing Dr. Leffmann's paper, stated that the subject was one of great importance, as the preservation of food-stuffs by means of preservatives was becoming more common daily. This practice was being carried on extensively, not only in the preservation of foods that were put up in air-tight vessels, such as canned goods and preserves, but likewise made use of in products that were exposed to the action of the air, particularly such very common food-stuffs as milk.

Naturally larger quantities of preservatives were necessary for the latter class than for the former.

It had become necessary to ascertain whether the preservatives that were commercially used were injurious to health or not, and the value of Dr. Leffmann's researches was readily shown by the fact that, as a result of these, the State of Pennsylvania had prohibited the use of salicylic acid as a preservative, and had permitted the use of sodium benzoate.

Dr. Leffmann's researches were in accord with others that had been made, particularly in reference to the action of salicylic acid on the digestive processes.

There was little doubt to-day that the use of salicylic acid as a preservative should be condemned; for the reason given by Dr. Leffmann sodium benzoate would be more allowable.

COMMITTEE ON SCIENCE AND THE ARTS.

THE VENTURI METER.

Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the inventions of Clemens Herschel, Frederick N. Connet and Walter W. Jackson.

HALL OF THE FRANKLIN INSTITUTE,
[No. 1,868.] PHILADELPHIA, May 4, 1898.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the "Venturi Meter," reports as follows:

The Venturi Meter is designed for the measurement of the flow of liquids in pipes of dimensions so great that the use of meters of the ordinary types, with movable parts, is impracticable.

The complete device consists of two distinct and widely different instruments, viz.: (1) the "Venturi," or meter proper, or meter tube, and (2) the registering apparatus.

The first part, *i. e.*, the meter proper, patented by Clemens Herschel, of Holyoke, Mass., April 17, 1888, No. 381,373, consists essentially of a mere constriction in the area of cross-section of the pipe, the flow in which is to be measured, with openings in the pipe opposite its normal and its constricted diameters, for measuring, by piezometers or pressure gauges, the pressures at those points; while the second part, *i. e.*, the register, patented by Messrs. Frederick N. Connet and Walter W. Jackson, of Providence, R. I., November 20, 1894, No. 529,365, consists of an elaborate mechanism, provided with clock-work and dials, by means of which the difference in pressure between the constricted and the normal sections of the Venturi tube is registered, at short intervals of time and in terms of the total discharge up to the termination of such intervals.

THEORY.

In the following statement of the theory of the Venturi meter, we shall, for convenience, assume that the water is a "perfect fluid," *i. e.*, a fluid free from viscosity and friction, although possessing mass (or inertia) and weight. (See Address to the Mechanical Section of the British Association, by William Froude, Esq., President, August 25, 1875.) This assumption will facilitate the exposition of the theory by eliminating from its discussion considerations not essential to its understanding; and the slight effects produced in the Venturi meter by such viscosity and friction as do exist in the water, will afterward be discussed in the proper place.

Let *Figs. 1* to *5* represent a Venturi meter tube, each with three piezometers in place, viz.: No. 1, over the tube up-stream from the constriction; No. 2, over the constriction itself; and No. 3, over the tube down-stream from the constriction. Let the unshaded area *W* in *Figs. 1* to *4*, represent the depths at which the water stands above any assumed horizontal datum plane *O-O;* and let the shaded area *A* represent the uniform pressure of the atmosphere, which, for convenience, we may suppose to be converted into some liquid of the specific gravity of water, but distinguishable, by its appearance, from the water.

The vertical distance, between the upper boundary of this latter area and any given point in the tube, represents the combined pressure of air and water at such point.

In *Fig. 1*, the water is at rest, and the tops of the water columns stand at one and the same level throughout, as do, also, the tops of the air columns; while, in *Figs. 2* to *5*, the water is in motion, as indicated by the arrows.

Now, if the tube were of uniform cross-section throughout, and if, as we assume, the water were a "perfect fluid" (*i. e.*, devoid of friction), the tops of the several columns, in *Figs. 2* to *5*, where the water is in motion, would still stand at the same level *with each other*, though at a lower one than before, owing to the consumption of a portion of the head in generating the velocity.

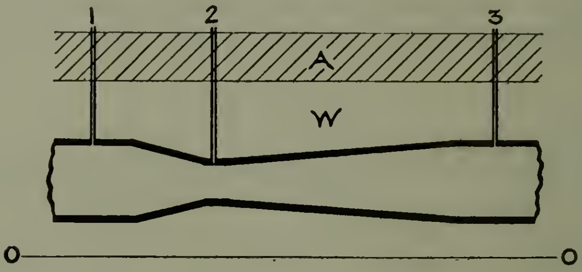

FIG. 1.

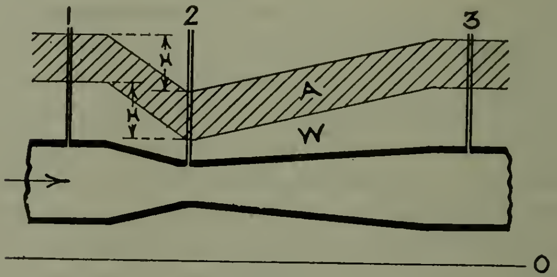

FIG. 2.

But, owing to the differences in the areas of cross-section of the pipe at the several portions of its length, the velocities vary, being necessarily inversely as the areas; and, as the heads corresponding to the several velocities are proportional to the squares of those velocities, the remaining or pressure heads must vary also, the smallest or lowest pressure head standing over the throat, where the velocity is greatest.

The increase of velocity, acquired by the fluid in passing from section 1 to section 2, is again given up in passing from section 2 to section 3; and in the case of a perfect fluid, the pressure lost between sections 1 and 2 would be perfectly restored in passing from section 2 to section 3. In practice, a small total loss occurs. This will be discussed in connection with the practical operation of the meters.

For a given head in piezometer No. 1 and given diameter of pipe at section 1, the expenditure of head in velocity between sections 1 and 2 increases as the area of the throat is diminished and as the throat velocity is thereby increased.

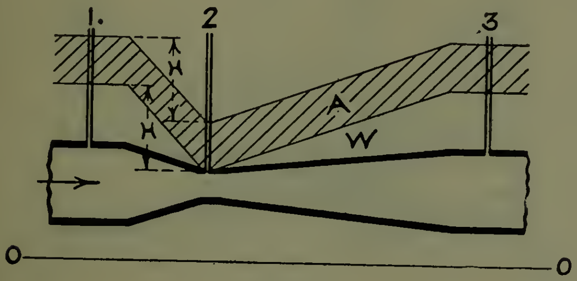

FIG. 3.

In *Fig. 3* is shown the case where all of the water head above the top of the throat is required to maintain the velocity through the throat.

In *Figs. 2* and *3* the head, *H*, expended in the increase of velocity between sections 1 and 2 is represented by the difference in level between the tops of the two water columns 1 and 2, or between the tops of the two corresponding air columns. In *Fig. 3* this difference is equal to the *total* vertical height of the water column at section 1 above the top of the throat at section 2.

If now (*Fig. 4*) the throat section be still further reduced (the other conditions remaining as before), the throat velocity will thereby be still further increased; for the *total* pressure available for increase of velocity between sections

1 and 2 consists not merely in the depth of *water* above the tube, but also in the *atmospheric pressure*, represented by the shaded area A above the water W.

In *Fig. 4* all the water has disappeared from piezometer 2, and even a portion of the liquid representing the air has also disappeared, leaving only a portion of the latter to represent such pressure as now remains in the throat. In other words, the pressure within the throat is now less than the atmospheric pressure. Hence, if an opening to the atmosphere were made in the throat, air would be drawn into the tube through such opening. The piezometer at section 2, however, excludes the atmosphere.

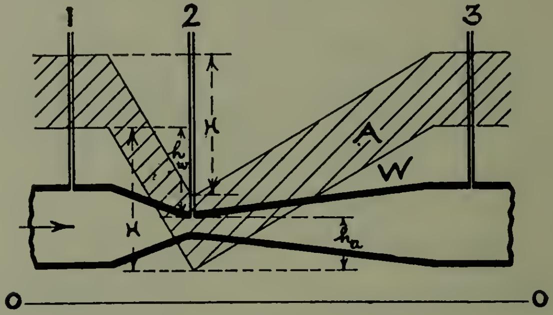

Fig. 4.

$H = h_w + h_a$

In *Fig. 4*, the loss of head, due to increase of velocity between sections 1 and 2, is $H = h_w + h_a =$ the entire available head of water, h_w, plus a portion, h_a, of the atmospheric pressure. The latter portion, h_a, is frequently called "the vacuum."

The top of the water column having now disappeared below the top of the throat, it is no longer feasible to ascertain the loss of head by taking the difference between the levels of the water surfaces in piezometers 1 and 2. If the air were visible, and if it were practicable to use a piezometer extending above the upper surface of the atmosphere, or (as we have supposed) to replace the air by a heavier fluid, we could arrive at the loss of head by taking (as before) the difference between the levels of the air columns at sections 1 and 2. In practice, the degree of "vacuum" may be found, as shown in *Fig. 5*, by using, in place of the piezometers, a glass tube bent over and led *downward* into an open vessel containing water or mercury. The height to which the water (or the mercury converted into feet of water) rises in this tube, shows the extent of the vacuum, or the portion, h_a, of the air pressure which has been called into service in producing the high velocity through the throat. By adding this to h_w, we obtain, as above, the total loss of head H between sections 1 and 2.

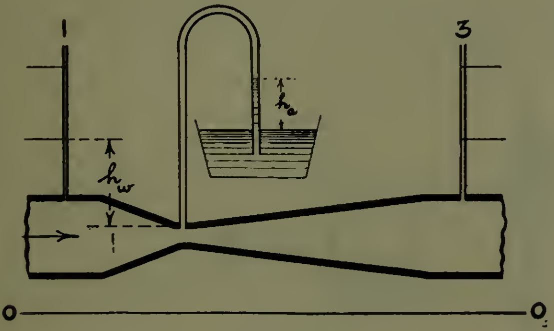

FIG. 5.
$H = h_w + h_a$

When the reduction of area at the throat has proceeded so far that the entire available pressure of water and air at section No. 1 is required, in order to maintain the corresponding velocity through the throat (*i. e.*, when the line representing the upper surface of the air falls to the level of the top of the throat), no further increase of throat velocity can be secured (with a given total head over section 1) by still further narrowing the throat. If the throat is further narrowed, the velocity through it will remain the same; and, the rate of discharge being thus diminished, the velocity through section 1 will be necessarily reduced. In other words, throttling begins.

Let v_1 be the velocity in section 1, above the throat, and v_2 the "throat velocity," or velocity in the throat or section 2.

Referring to *Fig. 6*, the velocity head at section 1 is

$$h_1 = \frac{v_1^2}{2g}$$

and the velocity head at section 2 is

$$h_2 = \frac{v_2^2}{2g}$$

Hence, the loss of head, between sections 1 and 2, or "the head on the Venturi," is

$$H = h_2 - h_1 = \frac{v_2^2}{2g} - \frac{v_1^2}{2g} = \frac{v_2^2 - v_1^2}{2g}$$

But, since the velocities are inversely as the areas of cross-section a_1 and a_2,

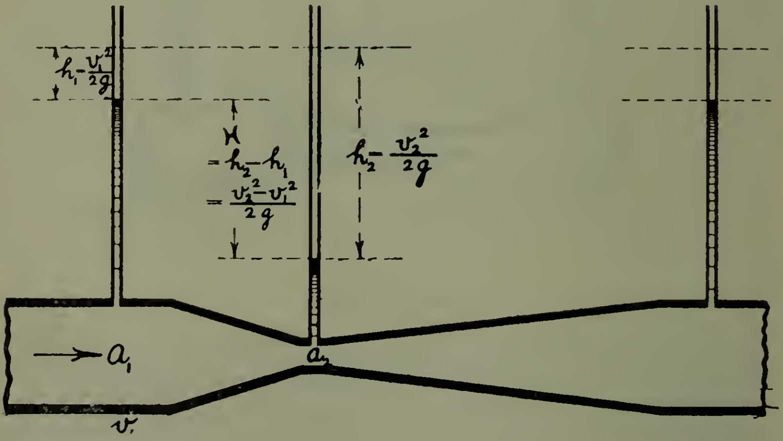

FIG. 6.

$$v_2 = \frac{a_1}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gH}$$

$$v_1 = \frac{a_2}{a_1} v_2 \text{ and } v_1^2 = \frac{a_2^2}{a_1^2} v_2^2$$

Hence

$$H = \frac{v_2^2 - \frac{a_2^2}{a_1^2} v_2^2}{2g} = \frac{\left(1 - \frac{a_2^2}{a_1^2}\right) v_2^2}{2g} = \frac{\frac{a_1^2 - a_2^2}{a_1^2} v_2^2}{2g}$$

$$v_2^2 = \frac{2gh\, a_1^2}{a_1^2 - a_2^2}$$

and throat velocity =

$$v_2 = \frac{a_1}{\sqrt{a_1^2 - a_2^2}}\sqrt{2g\,H}$$

The ratio

$$\frac{a_2}{a_1}$$

between the area a_2 of cross-section at the throat and that a_1 at the upper end of the up-stream cone, is called the throat ratio. For a throat ratio of 1 : 9 we have

$$\frac{a_1}{\sqrt{a_1^2 - a_2^2}} = \frac{9}{\sqrt{9^2 - 1^2}} = \frac{9}{\sqrt{80}} = \sqrt{\frac{81}{80}} = 1{\cdot}0062$$

or,

$$v_2 = 1{\cdot}0062\sqrt{2g\,H}$$

From the foregoing expression :

$$v_2^2 = \frac{2g\,H\,a_1^2}{a_1^2 - a_2^2} = 2g\,H \div \frac{a_1^2 - a_2^2}{a_1^2} = \frac{2g\,H}{1 - \frac{a_2^2}{a_1^2}}$$

we have

$$2g\,H = v_2^2 - \frac{a_2^2}{a_1^2}v_2^2$$

Hence,

$$v_2^2 = 2g\,H + \frac{a_2^2}{a_1^2}v_2^2$$

$$= 2g\,H + v_1^2$$

$$2g\left(H + \frac{v_1^2}{2g}\right)$$

and

$$v_2 = \sqrt{2g\left(H + \frac{v_1^2}{2g}\right)}$$

In other words, the velocity at the throat is that corresponding to the "head on the Venturi," plus the head corresponding to the velocity of approach in section 1.

THE VENTURI TUBE.

In practice, the Venturi tube, for pipes not over 60 inches in diameter, is formed of several short sections of cast iron pipe, having the required taper, and furnished with flanges, by means of which the sections are bolted together to form the two truncated cones required, as shown in *Figs.* 7, 8 and 9.

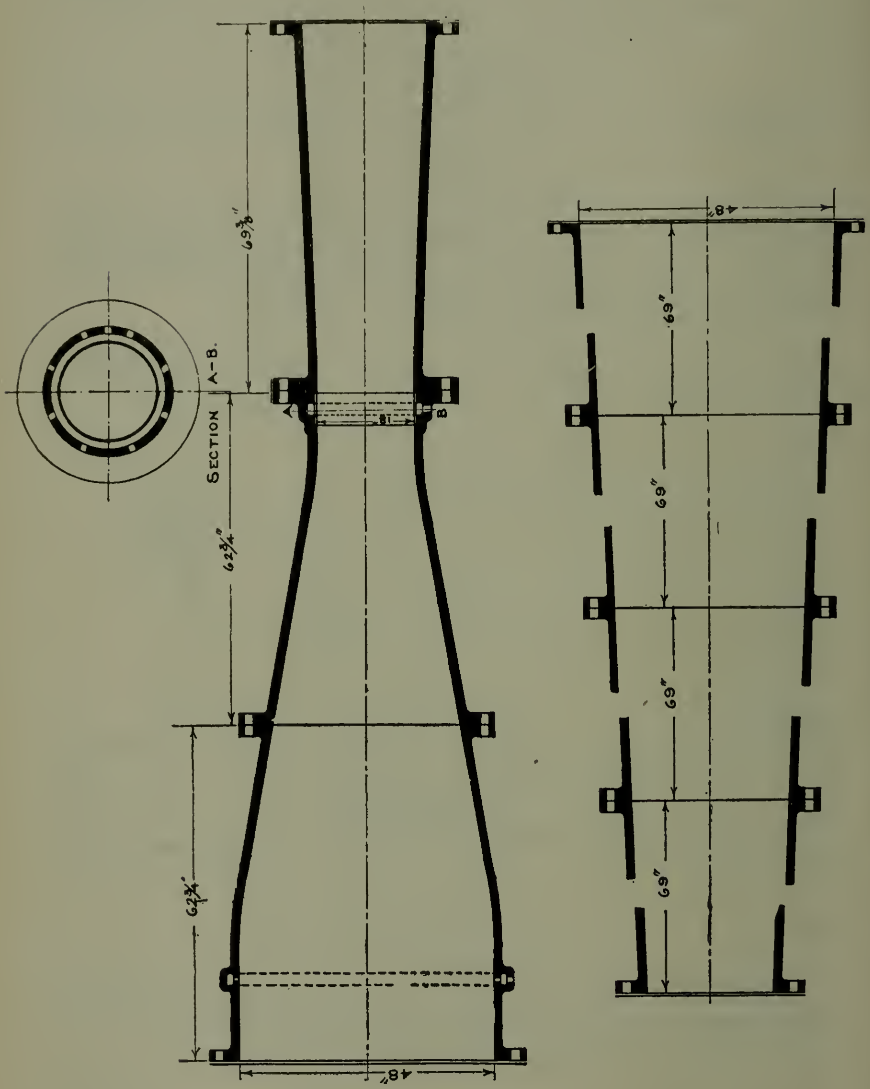

FIG. 7.—48-inch Venturi tube. Throat ratio, 1 : 7.

The throat section is generally made in a separate piece, and is either made of bronze or lined with that metal. (See *Fig. 7a.*)

The ends of the Venturi tube are furnished with either bell, spigot or flanged ends, according to the character of the pipe in which the tube is to be used.

For still larger streams, such as those in masonry conduits or riveted flumes, the Venturi tube may be made of wooden staves, sheet steel, cement concrete, brick or other suitable material, metal being used for the throat piece and where required by the pressure.

The throat piece is surrounded by an annular chamber called the pressure chamber, which communicates with the interior of the throat by means of several holes drilled radially through the walls of the latter at equal or nearly equal distances around the circumference.

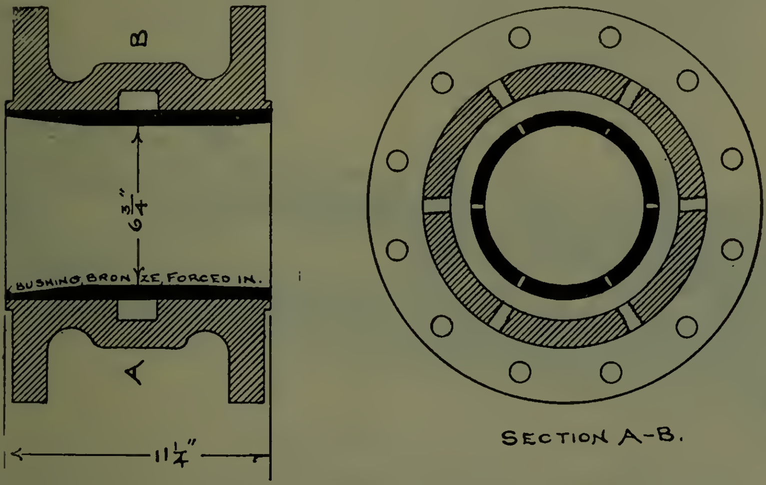

FIG. 7a.—Throat piece for 18-inch Venturi meter. Throat ratio, 1 : 7.

A similar pressure chamber is provided at the larger end of the short cone for observing the pressure in the normal section up-stream from the throat; and, if it is desired to ascertain the final loss of head due to the passage of the water through the Venturi, a similar chamber must be provided at the larger end of the longer or down-stream cone.

In designating the size of the meter, the diameter of the pipe of which it forms a part is used, and not the throat diameter. Thus, a meter for use in a 6-inch pipe is called a 6-inch meter.

Fig. 7 shows the construction of a 48-inch Venturi tube. Here the shorter cone, up-stream from the throat, is in two sections, and the longer one in five sections.

The cross-section shows a number of holes tapped radially through the outer wall of the pressure chamber. Of these, the one horizontally opposite the axis of the pipe is for tapping in the pressure tube connecting the throat with the register. The others are necessary for drilling holes connecting the pressure chamber with the throat.

In the smaller sizes, the shorter cone is generally in one section and the longer cone in two or more sections. (See *Figs. 8* and *9*, showing photographic views of a 4-inch and a 60-inch meter, respectively.)

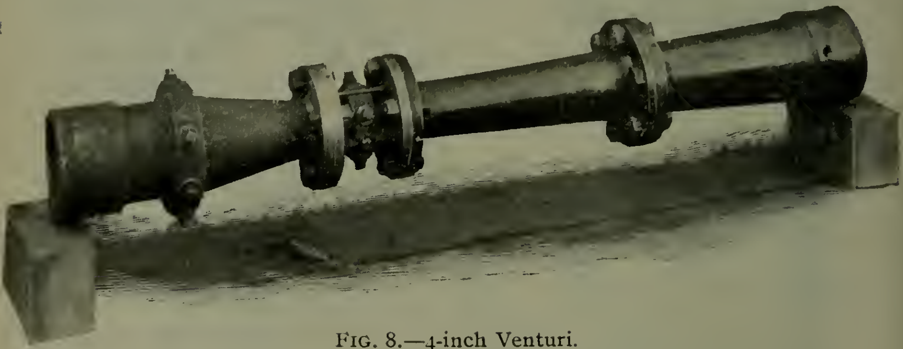

FIG. 8.—4-inch Venturi.

Mr. Herschel's original experiments were made at Holyoke, Mass., in June and October, 1887, with a 1-foot and a 9-foot Venturi meter. In both meters, the cones were formed of wooden staves, and the throat piece of cast iron, lined with brass.

THE REGISTER.

In the preceding discussion of the theory of the Venturi meter, we have, in order to facilitate the explanation, supposed the several pressures to be directly measured, as by piezometers or other suitable apparatus; and, indeed, this is sometimes done in practice, but such apparatus cannot *register* the flow. Furthermore, the measurement of the head does not directly give the velocity or the discharge; and the reading of a mercury column, with its relatively small variations, is necessarily inaccurate, while the use of water piezometers would, in most cases, be impracticable, owing to their great length. Besides, the piezometers show only the pressures existing at the moment, and give no continuous or cumulative statement of the discharge.

The register devised by Messrs. Connet and Jackson, and about to be described, gives periodic registrations, in which the pressure existing at the instant of registry is recorded in terms of the total discharge in cubic feet since the last registry and as an increase in the total number of feet registered. In other words, it gives a cumulative registry of the discharge, like that of a gas meter.

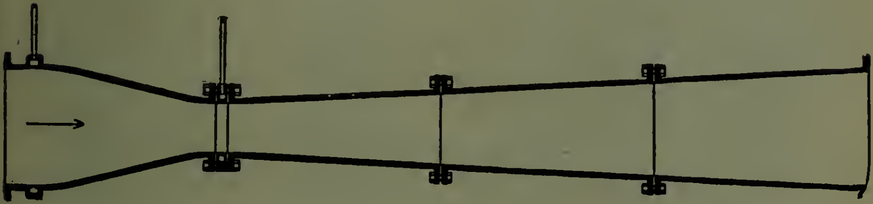

FIG. 8a.

Fig. 10 represents the register, together with the connections between it and the meter tube. These connections consist of two brass, lead, lead-lined or tin-lined tubes, *U-U* and *T-T*, *U-U* leading from the wide upper section 1, and *T-T* from the throat or narrow section 2. *U-U* carries the higher pressure of the water from section 1 into a well, *W*, containing mercury. From this well rises an inner tube, or barrel, *B*, also containing mercury, and communicating, through a narrow passage at bottom, with the well. The lower pressure existing (during flow) at the throat, is carried by the tube, *T-T*, into the upper portion of the register, and acts upon the surface of the mercury in the tube, *B*, rising from the well.

Let *m* denote the inches in depth of mercury in the tube, *B*, above the surface of the mercury in the well, and *w* the

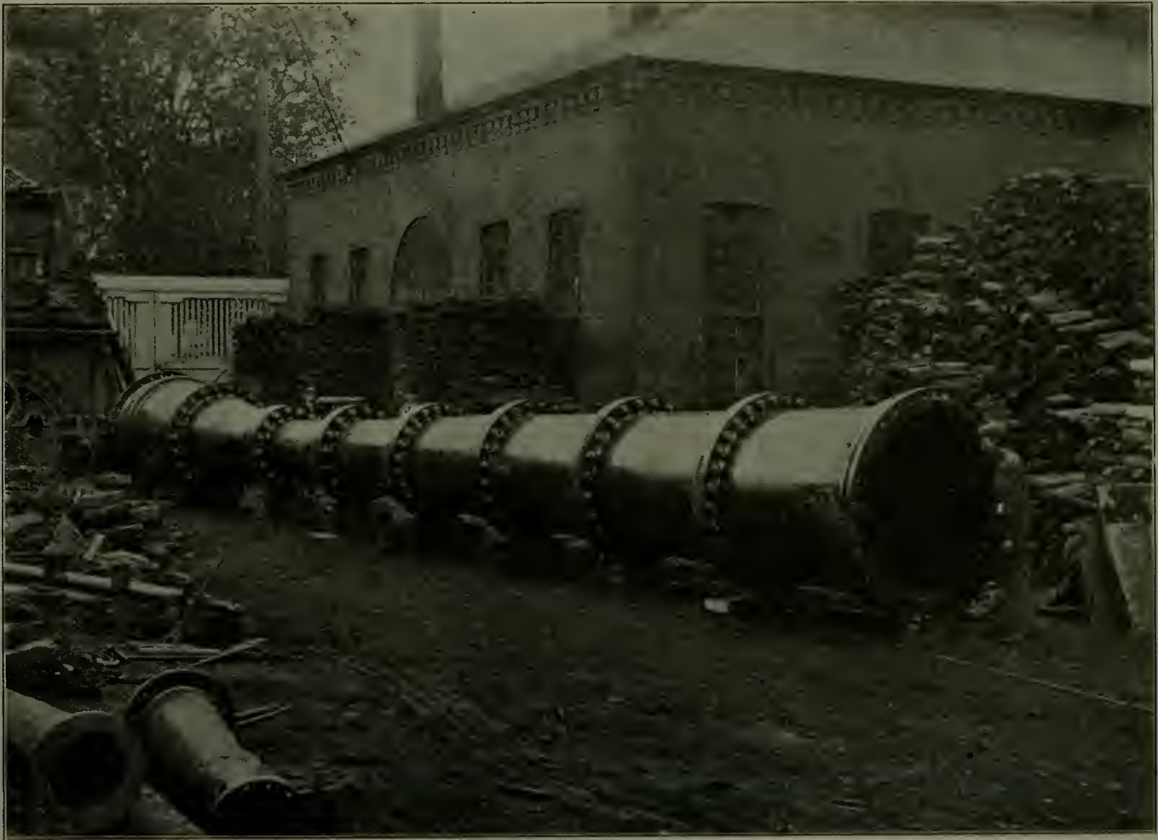

FIG. 9.—60-inch Venturi.

depth, in inches, of a mercury column equivalent in pressure to a water column of depth m. Then $m-w = H$, or the head on the Venturi, expressed in inches of mercury, and $1{\cdot}13\ (m-w) = H$ in feet of water.

We have now to describe the means by which this difference of pressure, which varies with the velocity, is made to record, periodically, the number of cubic feet which have passed through the Venturi tube.

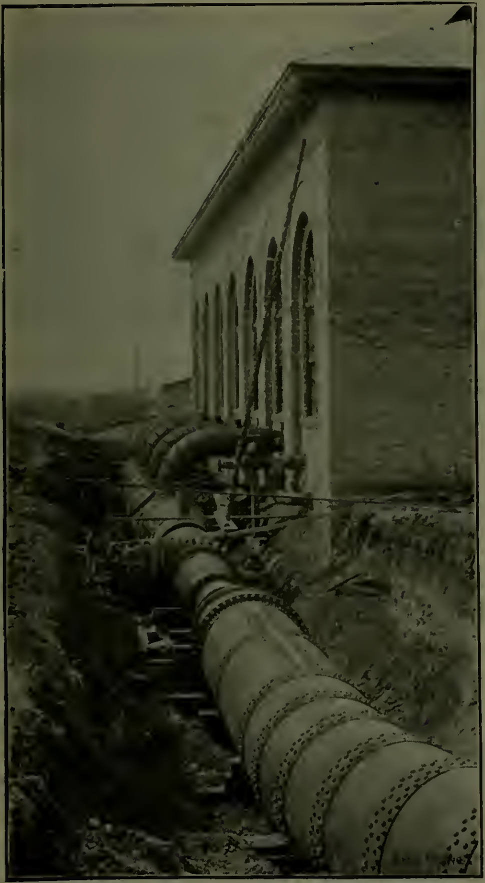

FIG. 9a.—60-inch tube at Ogden, Utah.

Upon the surface of the mercury in the tube, B, rests a float, $J\ V$, which carries, at its upper end, V, an idler wheel, *H*, with vertical axle. From what has been said, it will be seen that this idler wheel rises as the velocity through the meter tube increases, and sinks as the velocity decreases. By means of the spring, *S* (*Fig. 12*), the idler wheel is held constantly in contact with the surface of the drum, *I*, which is periodically revolved about its vertical axis, by means of the power mechanism indicated in *Fig. 10*.

The cylindrical surface of this drum consists, in fact, of portions of *two* cylinders, an inner or depressed surface, *D*, and an outer or raised one, *R*, the raised surface, *R*, being about $\frac{1}{8}$ inch farther from the axis than the depressed one, *D*. When the idler wheel rests against the *depressed* surface, *D*, as in *Fig. 11*, the drum is in gear with the pinion, *F*, by which its motion is transmitted to the counter shown in *Fig. 10;* but when the idler wheel rests against the *raised* cylindrical surface, *R*, as in *Fig. 12*, the drum and pinion are thrown out of gear, and the revolution of the drum is not recorded upon the counter.

The boundary between the two cylindrical surfaces, *R* and *D*, forming the drum (*Fig. 10*), is a spiral curve whose origin of co-ordinates is the position occupied by the idler wheel, *H*, when the drum is at rest and there is no flow in the meter tube, and when, consequently, the surfaces of the mercury in the tube, *B*, and in the well, *W*, are at the same level. The abscissas of the curve are the velocities of the water in the throat, and its ordinates are the corresponding heights to which the idler wheel rises above the origin or zero line. Inasmuch as the surface area of the mercury in the well, *W*, is double that in the tube, *B*, the ordinates are $\frac{2}{3}$ of the corresponding heads, *H*, in inches of mercury. The values of these ordinates are calculated from the results of careful experiments with a 48-inch Venturi meter.

Suppose the drum to be at rest, with the idler wheel, *H*, in the position shown in *Fig. 10*. As the idler wheel is resting against the depressed surface, *D*, of the drum, the drum and pinion are in gear. Now let the drum begin to revolve in the direction indicated by the arrow. The revolution of the drum will be recorded at the counter until the raised cylindrical surface, *R*, comes around to the idler wheel, which then rides up upon it, throwing drum and pinion out of gear, and terminating the registration for that revolution. Plainly, the greater the velocity through the throat of the Venturi meter tube, and the higher the position of the idler wheel, the longer time the drum and pinion will remain in gear during the revolution, and the greater will be the registration of discharge for that revolution.

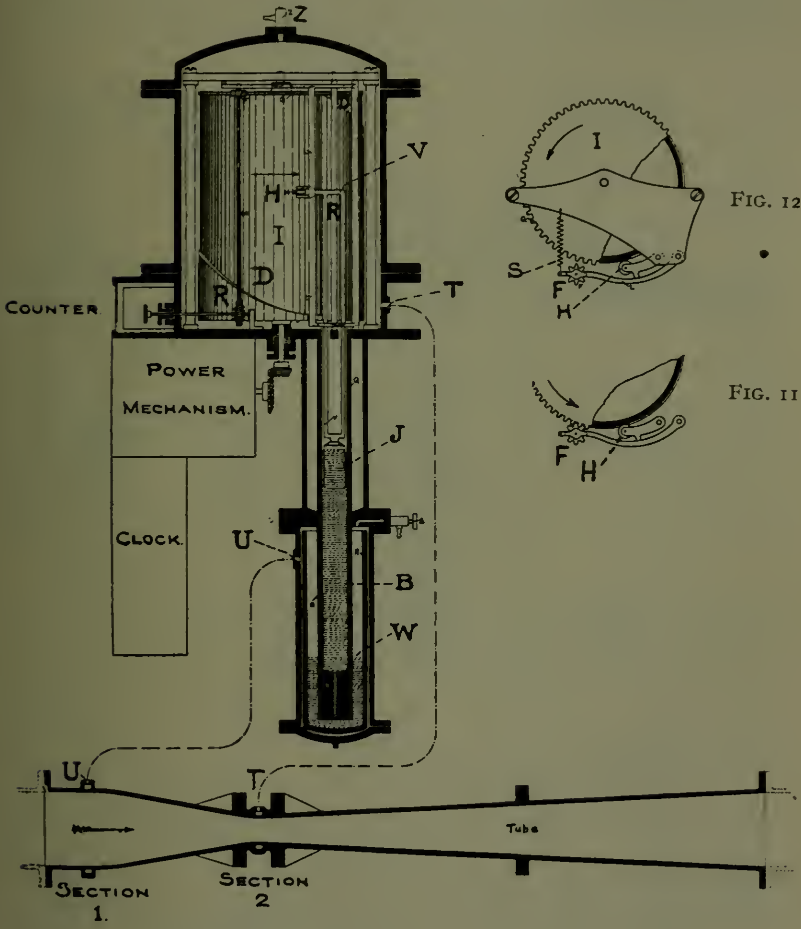

FIG. 12.

FIG. 11.

FIG. 10.

For difference in size of the meter tube, a difference is made in the gearing between the integrating drum and the counter, the drum remaining the same for all sizes. Strictly speaking, therefore, the drum speaks to the gearing in terms of the head on the Venturi, or of the corresponding velocity, while the gearing (constructed according to the dimensions of the Venturi tube) translates this message into cubic feet delivered during ten minutes.

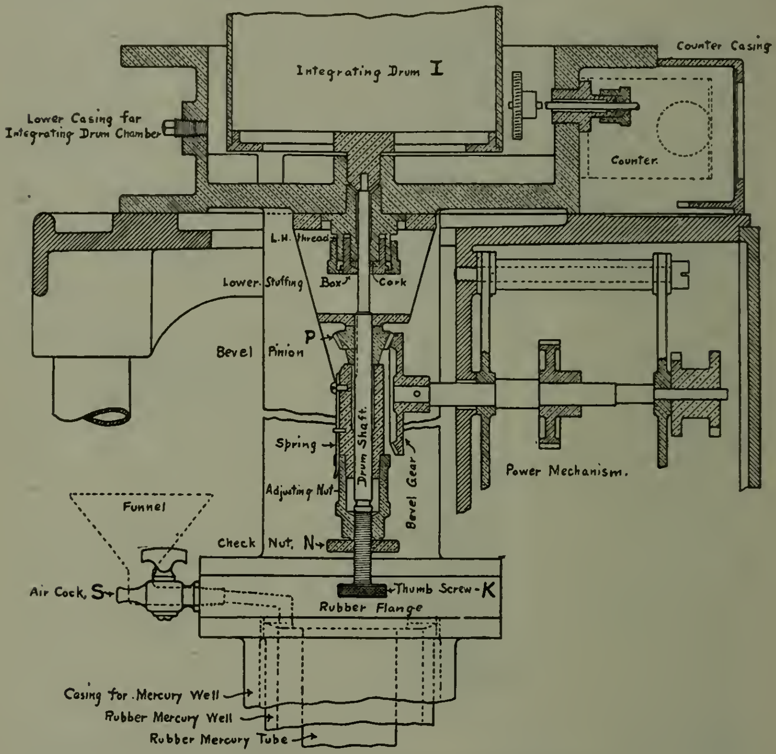

FIG. 13.—Section through lower portion of register.

The entire circumference of the drum represents a throat velocity of 38 feet per second. Hence, this is the highest velocity which can be registered.

At the boundary between the two cylindrical surfaces, *R* and *D*, a beveled surface is provided, to facilitate the passage of the idler wheel, *H*, from one to the other.

The mercury required in the tube, *B*, and well, *W* (*Fig. 10*), weighs 16½ pounds; but it will usually happen that a little more or a little less than this is actually introduced. Hence, the volume of mercury is variable, and the height of the float, for a given velocity or for no velocity, is variable also. To compensate for this variation, the integrating drum, *I*, is made adjustable by means of a thumb-screw, *K*, placed under the foot of the drum shaft, as shown in *Fig. 13*.

Figs. 14 and *15* are photographic views of the registering apparatus. *Fig. 15* is a front view, showing the entire length of the apparatus; while *Fig. 14* is a rear view of the principal portion, on a larger scale.

To introduce the mercury, the top of the dome is removed, and a cast iron funnel is screwed into its place, proper arrangement of the other valves and cocks being made for the exclusion of water and the escape of air.

When the instrument is in use, it must be entirely full of water, to the top of the dome, and free from air.

From time to time it becomes necessary to open slightly the air-cocks to permit the escape of air, especially when much air is contained in the water. This may be done while the apparatus is in use, but not while the drum is revolving.

The large weights shown in *Figs. 14* and *15* drive the power mechanism, which, once in ten minutes, turns the integrating drum through one revolution. This motion occupies a few seconds and is transmitted to the counter so long as the idler wheel rests upon the depressed surface, *D*, of the drum. This depends, as already explained, upon the height of the idler wheel, and this, in turn, upon the throat velocity. Upon this latter depends, again, the quantity of water passed through the Venturi during the ten-minute period. Thus the quantity registered is made to correspond with the quantity actually discharged.

The release or tripping of the power mechanism, once in ten minutes, is effected by an eight-day clock, provided with a separate weight.

The tripping may be done by hand, at shorter intervals, whenever this is desired, but it must then be remembered

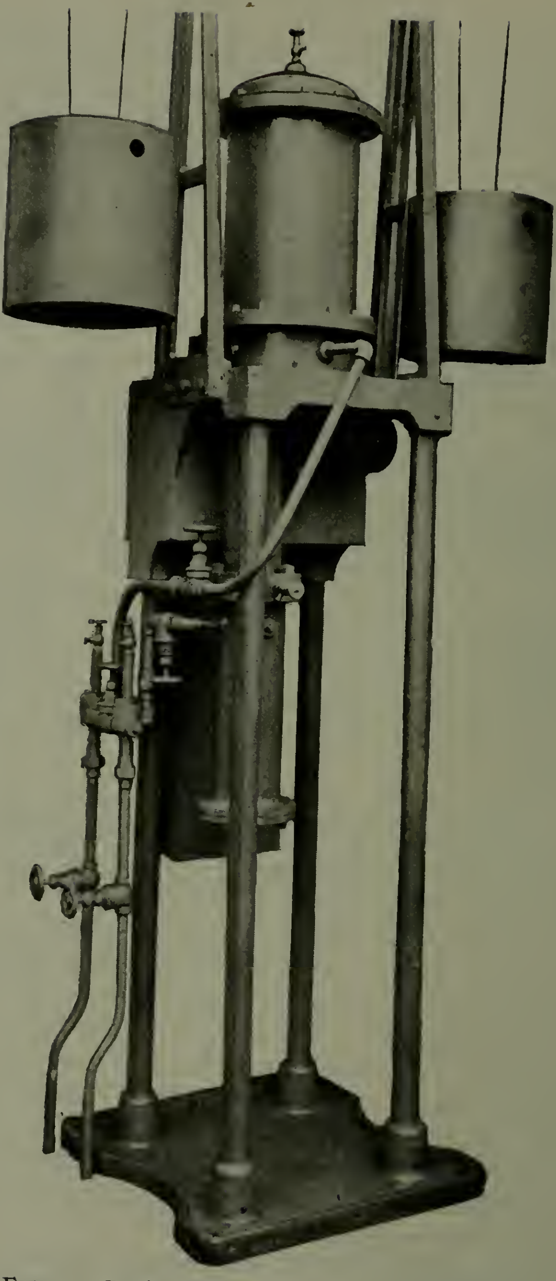

FIG. 14.—Register. Rear view of lower portion.

that the registration, at each tripping, shows the quantity discharged *in ten minutes*, regardless of the time which has actually been allowed to elapse since the last tripping, and a corresponding correction must be made. If, for instance, the mechanism is tripped at intervals of two minutes, each increment in the registration must be divided by five.

A gain or loss, by the clock, of fourteen minutes in twenty-four hours, causes an error of about 1 per cent. in the reading.

The register may be placed at a considerable distance (not exceeding, say, 500 feet) from the Venturi tube. It must be placed at such a depth below the hydraulic grade line that the pressures existing in the Venturi tube shall at all times be transmitted to the two mercury surfaces.

The pipe lines must be covered, and a shelter from weather and frost must be provided for the register. If suitable accommodation for the latter is not available in some existing building, a frost-proof vault or register-house, not less than 6 feet square and 6 feet high, must be constructed.

The counter may be either straight-reading, like that of a revolution indicator, or provided with dials and pointers, as in a gas meter.

The registration may be automatically transmitted, by electricity, through any desired distance, to a secondary or office dial, shown in *Fig. 16*.

BEHAVIOR.

As already stated, the complete device forming the Venturi meter consists of two distinct instruments, manufactured under different patents issued to different patentees, viz.: (1) the Venturi tube, and (2) the registering apparatus. The character of the results obtained depends, therefore, jointly upon the behavior of each of these parts.

As to the Venturi tube itself, it is a demonstrable fact that, as already stated, with a perfect (*i. e.*, frictionless) fluid, the indications of the piezometers would form an infallible and exact index to the velocity, and that the pressure lost during the contraction of the stream would be perfectly

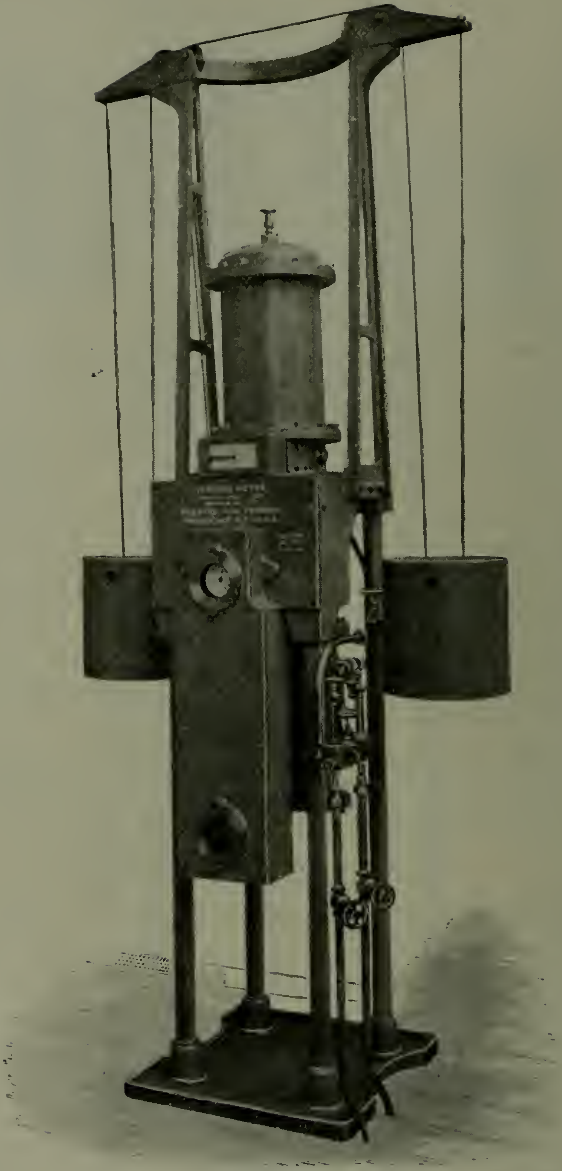

FIG. 15.—Register.

restored during its subsequent expansion, so that there would be no resulting loss of head.

It has long been known that, with a certain form of mouthpiece, approaching the shape of the "vena contracta," these conditions could be almost perfectly obtained in practice; and experiments with the Venturi tube have shown quite clearly that in it a very satisfactory approximation to these conditions is obtained.

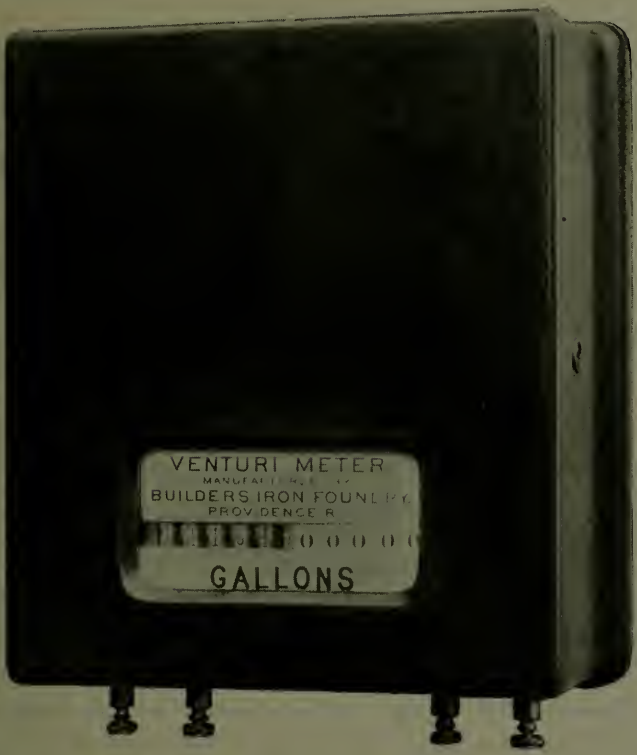

FIG. 16.—Office register.

Furthermore, in the present state of the mechanic arts there is no difficulty in forming the throatpiece so perfectly that the discharge can be very closely inferred from the throat velocity.

The construction of the tube is so simple, so strong and so little subject to wear or disarrangement, that, apart from these purely hydraulic questions, there is but little to investigate so long as the conditions are normal. Certain matters, respecting its behavior in practical use under trying conditions, will, however, be mentioned further on.

The registering apparatus, on the contrary, is an elaborate piece of machinery, composed of many delicate moving parts. It is therefore important, in studying it, to ascertain, not merely whether it is so designed and constructed as to register faithfully the indications of the piezometers, but also whether, after long-continued use, it remains a practicable and serviceable tool, or whether its delicacy and its consequent liability to derangement, are such as to militate against its usefulness, and so interfere with the availability of the entire device.

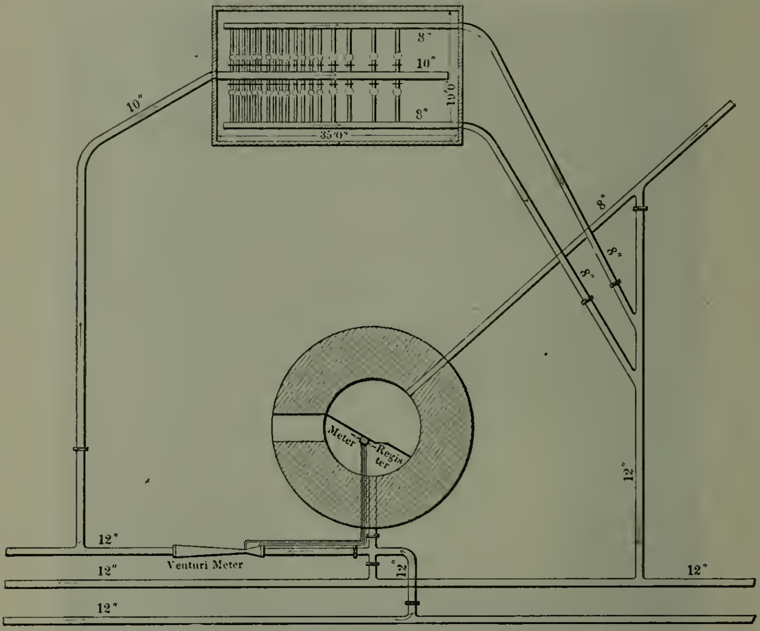

FIG. 17.—Chestnut Hill, Philadelphia.

It is for this reason that your sub-committee would hardly have been justified in making a much earlier final report, even if its members had had the necessary time at their disposal.

As already stated, the first recorded experiments with the Venturi meter were those of its inventor, Mr. Clemens Herschel, described by him in *Transactions* of the American Society of Civil Engineers, November, 1887, Vol. XVII, p. 228.

These experiments were made at Holyoke, Mass., in June and October, 1887, with two Venturi tubes made of wooden staves with cast iron throatpieces lined with brass. One of these was about 1 foot in greatest diameter; the other, nine times as large, was placed in a flume of nearly circular cross-section, about 9 feet in diameter. In each, the throat ratio, or ratio of area of cross-section in throat of Venturi to that in the up-stream end of the tube, was 1 : 9, the diameters being as 1 to 3. The pressures within the Venturi tubes were measured by piezometric columns, that leading from the throat being immersed in an open vessel containing water, as indicated in *Fig. 5* herewith. The discharge through the smaller Venturi tube was measured in a tank, the dimensions of which were accurately ascertained, while that through the larger tube was measured over a weir. The

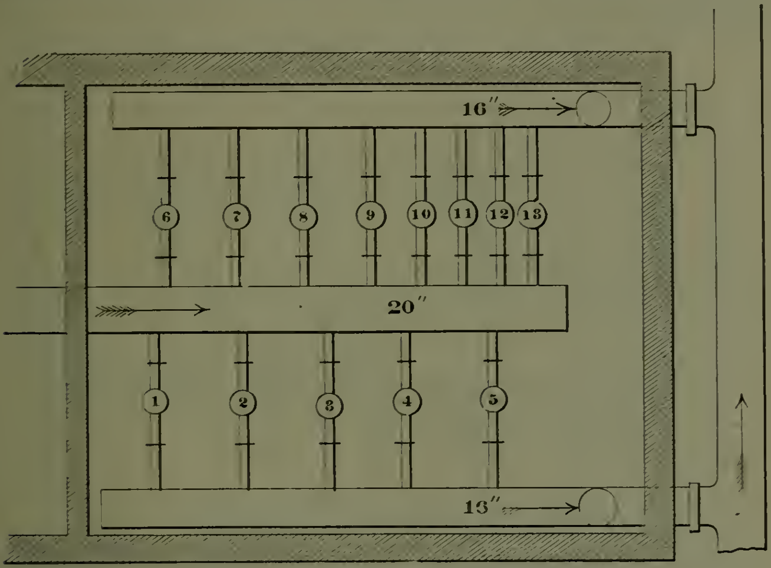

FIG. 17a.—Chestnut Hill, Philadelphia.

smaller Venturi tube formed nearly the entire length of the pipe used in that case, receiving its water from a forebay and discharging it into a wooden box only 22 feet distant; but the flume in which the larger tube was placed was 224 feet long, and the conditions in that case, therefore, more nearly corresponded with those obtaining in lines of water pipe.

For throat velocities varying from 9 to 50 feet per second (corresponding to pipe velocities from 1 to 5·5 feet per second) in the smaller Venturi, and from 4 to 35 feet per second (pipe velocities, say 0·5 to 4 feet per second) in the larger one, Mr. Herschel obtained for the formula,

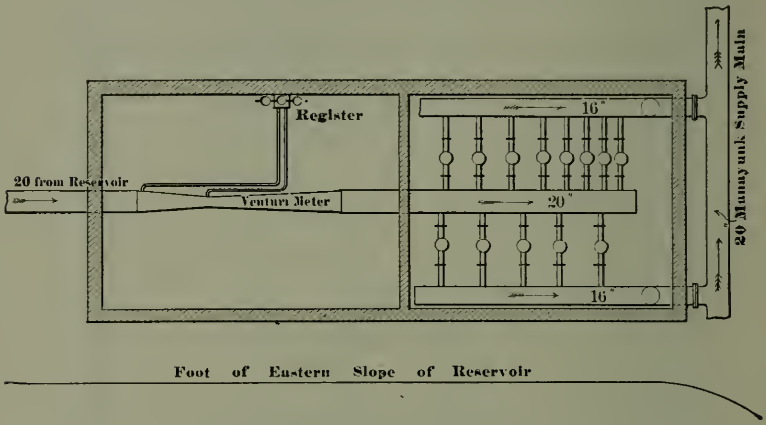

FIG. 18.—Roxborough, Philadelphia.

$$v_2 = C\frac{a_1}{\sqrt{a_1^2 - a_2^2}}\sqrt{2gH} = C\sqrt{2g\left(H + \frac{v_1^2}{2g}\right)}$$

coefficients, *C*, varying only from about 0·95 to 1·00. In other words, within the range of velocities named, the Venturi showed, in general, a discharge less than the measured discharge by from 0 to 5 per cent.

Similar results were obtained by Mr. Herschel with a 48-inch Venturi meter on a main of the East Jersey Water Company, at Macopin, N. J., in November, 1891. (See Journal of the New England Water Works Association, Vol. VIII, No. 1, September, 1893.)

The following series of experiments with Venturi meters have been made by Mr. A. J. Fuller, Assistant in Charge of Distribution of the Bureau of Water, Philadelphia, under the supervision of your sub-committee:

(1) Belmont Pumping Station, November–December, 1895, 6-inch Venturi, throat ratio, 1 : 9. Discharge measured in tank 17 feet in diameter, 6 feet deep.

(2) Chestnut Hill Pumping Station, 1896-98. 12-inch Venturi, throat ratio, 1 : 9. Discharge passed through a nest of small meters. *Figs. 17* and *17a.*

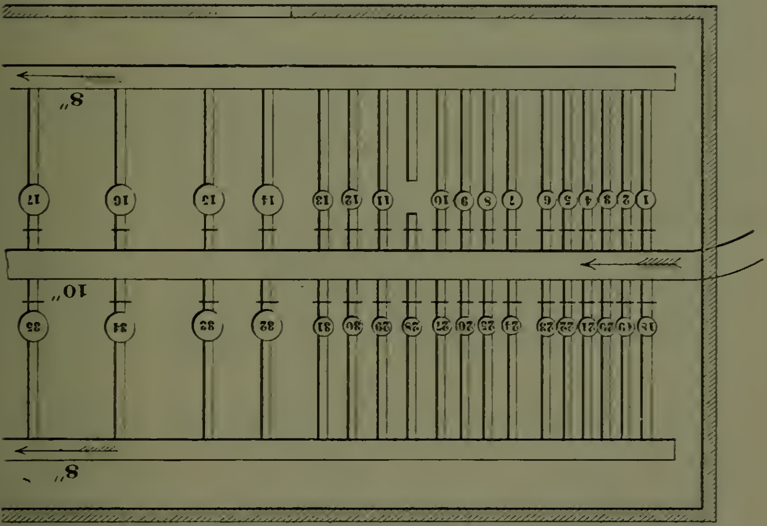

FIG. 18a.—Roxborough, Philadelphia.

(3) Old High-service Pumping Station, Roxborough, 1896–98. 20-inch Venturi, throat ratio, 1 : 7. Discharge passed through a nest of small meters. *Figs. 18* and *18a.*

(4) Wentz Farm Reservoir, 1896–98. On pumping main. 48-inch Venturi, throat ratio, 1 : 7. Discharge measured over a weir.

(5) Frankford Pumping Station, 1897-98. 48-inch Venturi, throat ratio, 1 : 7. On same pumping main with No. 4. Discharge measured over same weir.

As these experiments were inaugurated chiefly in order to ascertain the suitability of the entire device to the needs of the Bureau of Water, and only secondarily as a source of information to your sub-committee, and as the correctness of the Venturi principle had already been pretty well established, no great refinement was attempted in making or recording the experiments. In general, however, the results obtained confirmed those mentioned above as given by Mr. Herschel, the discrepancy between the Venturi readings and the accepted standard (tank or weir measurement, as the case may be) being usually within 3 per cent. This included the operation of the registering apparatus, which was generally found to tally closely with the results obtained from readings of mercury piezometers.

At Belmont (Series No. 1) considerable trouble was experienced, particularly in connection with the electrically driven register there used, in getting fairly under way. On December 23, 1895, the following results were obtained (discharge measured in tank):

Test No.	Throat Velocity. Feet per Second.		Percentage of Error.
1	22·90		— 0·92
2	6·80		+ 5·25
3	6·80	1st adjustment	— 1·77
4	6·80	2d "	— 2·64
5	6·75	3d "	— 1·87
6	6·75	4th "	— 0·28
7	22·00		— 0·76
8	33·5		+ 0·17
9	10·1		+ 0·75

The adjustments here noted consisted in raising or lowering the integrating drum by means of the thumb-screw, *K* (*Fig. 13*), to make the height of the idler wheel, under static conditions, coincide with the level of the origin of co-ordinates of the curve inscribed on the drum.

At Chestnut Hill and at Roxborough (Series 2 and 3) the water, after passing through the Venturi, was passed through nests of small mechanical meters, all of which had been carefully tested.* Comparisons were made, also, between the readings of the Venturi register and those of mercury piezometers.

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* The discharges here given for the mechanical meters are those obtained after making correction in accordance with the tests of those meters.

The following results are recorded:

COMPARISONS BETWEEN VENTURI REGISTER AND MECHANICAL METERS. CHESTNUT HILL, JUNE 3 TO DECEMBER 31, 1896.

	Cubic Feet.	Per Cent.
Mechanical meters,* 4-inch and 6-inch	1,897,084	
Venturi meter, 12-inch (register)	1,910,480	
Venturi in excess	13,396 =	+ 0·706
Mechanical meters,* ½-inch to 4-inch	6,341,479	
Venturi meter, 12-inch (register)	6,361,570	
Venturi in excess	20,091 =	+ 0.317

ROXBOROUGH, OCTOBER 22 TO DECEMBER 31, 1896.

Mechanical meters,* 2-, 3-, 4- and 6-inch	14,434,004	
Venturi meter, 20-inch (register)	13,917,835	
Venturi in deficiency	516,169 =	— 3·576 †

COMPARISONS BETWEEN VENTURI REGISTER AND VENTURI MERCURY PIEZOMETER, CHESTNUT HILL.

June 3, 1896. Register 0·1 per cent. less than mercury piezometers.
June 5, 1896. Register 0·2 per cent. less than mercury piezometers.
Oct. 29, 1896. Register 1·2 per cent. less than mercury piezometers.

ROXBOROUGH.

Oct 28, 1896. Register 0·50 per cent. more than mercury piezometers.

The meters at Wentz Farm, No. 4, and at Frankford Pumping Station, No. 5, were placed upon the pumping main from the Frankford Station to the Wentz Farm Reservoir, a 48-inch main, four miles long. No. 4 was first placed upon this main, near the reservoir.

In a test of this meter by Prof. H. W. Spangler, of the University of Pennsylvania, November 19–23, 1896, the Venturi gave results from 0·5 per cent. to 5·2 per cent. less than those obtained from the weir, with an average deficiency of 2·1 per cent.; but, as very fitly remarked by

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† Near the close of these experiments it was discovered that at times the draught upon the system had been so great as to draw water from the dome containing the integrating drum of the register. This is regarded as having increased the discrepancy in this case.

Mr. Herschel, a comparison of results between a weir and a Venturi meter is a test rather of the skill of the person manipulating the weir than of the correctness of the Venturi. In this case, the weir was placed at the end of an open box, 4 feet deep, 13 feet wide and 70 feet long, the pumping main discharging vertically upward into the box near its other end. Hook gauge readings were taken in a rectangular chamber adjoining and communicating with the weir box. The agitation of the water was reduced, as far as possible, by placing floats in the weir box. These reduced the maximum oscillation in the hook gauge box to about 0.04-inch and the usual allowance was made for velocity of approach; but the arrangements connected with the weir were still far from ideal.

In connection with these experiments, it was found that the register could be so adjusted as to read in practical identity with the weir.

Another series of tests, made by the Bureau of Water, November 23–24, 1896, gave the following results, as compared with those of the weir above mentioned:

Date 1896.	Throat Velocity deduced from weir. Feet per second.	Percentage of error.	
		Mercury column.	Venturi register.
November 23.	17·1	+2·60	—4·41
" "	21·4	+1·79	—1·91
" "	24·3	+2·16	—0·88
" "	28·0	+2·69	+0·02
" "	31·7	+2·68	+0·03
" 24.	17·4	+0·91	—1·27
" "	20·6	+2·76	+0·68
" "	24·6	+3·37	+1·07
" "	27·6	+9·98	+7·44
" "	32·1	+3·10	+0·50

On June 10, 1897, this meter was removed to the Frankford Pumping Station, where it was placed upon the same pumping main as before, and was used, June 16–19, in measuring the delivery of the engine recently completed there by the Southwark Foundry and Machine Company, of Philadelphia.

The water was measured, also, over the weir at the Wentz Farm reservoir.

During the high-speed test of the pump, the Venturi recorded 4·6 per cent., and during the low-speed test 10·7 per cent. more water than the weir; but it is altogether probable that a considerable portion of this was diverted, through partly open stops or leaky pipe joints, between the Venturi and the weir at the reservoir.

Later an additional 48-inch Venturi meter was placed upon the same main near the reservoir, at the location formerly occupied by the one already mentioned. The two meters, 4·24 miles apart, were thus placed in tandem, so that their registrations could be compared, for the purpose of estimating the amount of leakage from the intervening main.

The first test under these conditions was made October 26, 1897, when the lower meter showed 4·16 per cent. greater flow than the upper one. Investigation showed that a part of the water which passed through the lower meter, was diverted, through a leaky stop, from the 48-inch main, on which the two Venturis were placed, into the 30 inch pumping main, and a pump was started on this latter main, in order to equalize the pressures in the two mains and thus reduce the leakage from one to the other. The 30-inch main discharged beneath the water level in the reservoir. The pressures in it were, therefore, necessarily at all times less than those in the 48-inch main which discharged through the weir placed about 16 feet above the water level in the reservoir.

Under these conditions the mercury columns of the two meters were read, and the lower one averaged 0·63 per cent. more than the upper one.

A comparison between the Venturi register and the mercury column, on June 10, 1897, showed the register 0·8 to 3·9 per cent. in deficiency.

The investigations of the Philadelphia Bureau of Water, although perhaps of limited scientific value, have sufficed to satisfy the Bureau thoroughly as to the value of the Venturi meter as a means for determining the discharge of water pipes and as to the desirability of extending its use in the service of the Bureau.

An 18-inch Venturi meter, throat ratio 1 : 7, was installed at Spring Creek Temporary Driven Well Station of the Brooklyn Waterworks, December 16, 1896, and shortly afterward tested in comparison with a weir. We are indebted to Mr. I. M. de Varona, Engineer of Water Supply, for a report of this test, according to which the Venturi gave a discharge about 5 per cent. greater than the weir by Francis' formula, and about 1·5 per cent. greater than by Hamilton Smith, Jr.'s formula.

At Lawrence, Mass., a Venturi meter in a 30-inch main was tested, on the 20th of April last, in comparison with a weir, at a nearly uniform velocity. The mean discrepancy between meter and weir, for a series of eighteen observations, was 0·6 per cent., with the meter in excess, and the greatest discrepancy in any of the tests was 4·93 per cent., with the meter in excess. In connection with the figure last named, it should be borne in mind that the smallest division of the register corresponded to a flow of 1,000 cubic feet, so that it was necessary to estimate the hundreds, and, as the total flow at each observation was only about 4,400 cubic feet, this would account for a considerable discrepancy. Mr. R. A. Hale, of the Essex Company, has kindly furnished these data.

Your sub-committee obtained, from the builders of the Venturi meter and register, the Builders Iron Foundry, of Providence, R. I., a list of all persons and corporations using the device, and addressed inquiries to all of them, soliciting information as to their experience with it. The results of this correspondence are embodied in the following:

The first registers made were provided with weight-driven mechanism; but, in order to obviate the necessity of frequently winding these, an electrically driven mechanism was substituted. This, however, owing to the uncertainty of the action of the batteries used, proved almost universally unsatisfactory. The Builders Foundry recognizing this, has abandoned the manufacture of electrically-driven registers and is replacing with weight-driven registers those furnished. Except for the necessity of winding them twice each week, these give general satisfaction. The foregoing has been the experience of the Philadelphia Water Bureau, as well as of nearly all our correspondents.

A letter received from the Water Commissioner of Clinton, Mass., stated that a 16-inch meter had failed to record parts of two days' results, owing to corrosion of a wheel in the register. During the summer of 1897 the electrically driven register was replaced by one driven by weights, and this has since run without a break.

Mr. George Kent, of London, who represents the Venturi meter in England, sends a drawing, showing an application of the Venturi meter to the purpose of showing the condition of a filter bed.

Mr. F. L. Cushing, Water Registrar, Medford, Mass., reports that in January, 1897, the 12-inch meter in use there gave unsatisfactory results, owing to a chip, which had lodged in the throat. The throat ratio of this meter is not given, but, if it was as great as 1 : 9, the throat diameter was 4 inches, so that it must have required a chip of respectable dimensions to lodge in the throat. Nevertheless, manholes have been provided, above and below the meter, to facilitate the removal of such obstructions.

One of the principal advantages of the Venturi meter is, that, owing to its unobstructed channel, free from moving parts, it is far less liable to clogging than the forms of meter in common use. Most of the solid bodies which would inevitably clog and stop any form of mechanical meter, would pass freely through the unobstructed throat of the Venturi.

On July 23, 1897, the Medford meter, which, in the meantime, had been furnished with a weight-driven register, was tested, in comparison with a square gate-house, of accurately known dimensions, which was used as a measuring tank. Eight tests were made, and the average flow, by the Venturi register, was 1·37 per cent. less than the flow as measured by the tank. The Venturi readings ranged from 3·65 per cent. less to 0·77 per cent. greater, than the measured flow. The rate of flow remained uniform during the test.

Mr. Dexter Brackett, Engineer of Distribution Department, Massachusetts Metropolitan Water Board, writes that since February, 1896, the Board has had a 36-inch Venturi in a pumping main, supplied by two Gaskill engines, near the Chestnut Hill Pumping Station. The discharge has ranged from 8,000,000 to 20,000 000 gallons per day. Indications, obtained by comparing the plunger displacement of the engines with the meter record, show that the latter is probably within 2 per cent. of the truth. One of the engines shows a slip of between 7 and 8 per cent., and the other about 3 per cent., as compared with the meter record. The weight-driven register has thus far worked very satisfactorily.

The De Kalb Electric Company, of De Kalb, Ill., which has a 12-inch meter, has had an electrically driven register in use about two years, and considers it a very satisfactory arrangement.

E. and T. Fairbanks & Co., of St. Johnsbury, Vt., have a 10-inch meter, with an office counter at the factory, two miles distant. At one time, the counter registering abnormally large volumes of water, an investigation was made, and it was found that a break in a distributing pipe was carrying large quantities of water directly into the sewer.

Prof. Dwight Porter, of the Massachusetts Institute of Technology, Boston, has a 3-inch meter, throat ratio 1 : 9, without register. Comparing the actual discharge with that theoretically due to the head on the Venturi, one set of experiments gave a coefficient varying from 0·98 for throat velocity of 27 feet per second, to 0·995 for a throat velocity of 72 feet per second. A later series of 45 tests, by other experimenters, gave a coefficient varying from about 0·95 to about 0·985 (with three exceptions) for throat velocities from about 7 to about 40 feet per second, no regular law of variation appearing.

From unsatisfactory results given by another test, with a 12-inch meter on a pumping main, Professor Porter is inclined to question the adaptability of the device to such service; but the satisfactory results obtained with the 36-inch meter in Boston, and with the two 48-inch meters in Philadelphia, all on pumping mains, would indicate that his misgivings are unfounded.

The Solvay Process Company, of Syracuse, N. Y., has a 12-inch and an 8-inch Venturi meter, measuring brine, under a pressure of about 40 pounds, and two 5-inch Venturis measuring very hot boiler-feed water at a pressure of about 145 pounds. Weight-driven registers are used, except on one of the brine meters, and are less liable to get out of order, and require less watching, than the electrical register, which, however, is reported as very satisfactory.

The brine meters work very satisfactorily indeed. As tested very accurately, by a chemical test, they are found to vary not more than from 1 to 1½ per cent.

The discharge from the hot-water meters is measured in a tank, and the error of the meters, when in good condition, is found to be within the errors of tank measurement, although the tank is measured with exceptional care and checked by means of a recording gauge. It is found that the meter record is at least as trustworthy as the tank measurement, if not more so. Owing, however, to the presence of carbonate of lime in the feed water, even after treatment with soda, some scale forms in the Venturi throat, causing the apparatus to give readings in excess of the truth. This necessitates frequent cleaning of the Venturi.

"The mechanically driven registering apparatus gives no more trouble than any good clock."

The North Packing and Provision Company, of Somerville, Mass., has had a 4-inch meter in use since December 20, 1897, registering daily over 91,000 gallons of water at an average temperature of 210° Fahr. It gives entire satisfaction.

Many other replies have been received, but the foregoing embodies the substance of the correspondence.

Mr. Herschel's experiments with a 48-inch Venturi, at Macopin, N. J., already quoted, gave a total loss of head, due to the passage of the water through the two cones and throat, forming the meter, of about 0·106 foot for each foot of head on the Venturi.

Professors Marx, Wing and Hoskins, experimenting with two 54-inch Venturi meters at the power-house of the Pioneer Electric Power Company, at Ogden, Utah (Proceedings, American Society of Civil Engineers, Vol. XXIV, No. 5, May, 1898), found a loss of head of 0·149 foot, per foot of head on Venturi. This would make the added force required by the Venturi, in pumping 20,000,000 gallons daily through a 48-inch Venturi meter, with throat ratio 1 : 9, about 1·12 feet. It was found that dirt collected on the surface of the column of mercury in the third or last piezometer, causing uncertainty, amounting probably to not more than 0·004 foot, in the readings for total loss of head. This trouble was not experienced with the throat and up-stream piezometers.

The Ogden meters received their water from a riveted steel main 6 feet in diameter, over 4,000 feet in length, with a head of nearly 400 feet above the meters. The steel main, in turn, received it from a wooden flume, 6 feet in diameter, about 3,000 feet long, with a head of about 50 feet, making a total length of about 7,000 feet of 6-foot pipe, with a total head of 462 feet. It was found that, after changes in the rate of flow, it required about fifteen minutes for the flow and pressures in the pipe to become steady. The Venturi meters, on the contrary, become steady in not more than two or three minutes.

Venturi tubes are made with throat ratios ranging from 1 : 4½ (or 2 : 9) to 1 : 16. The former are adapted to high, and the latter to low velocities; for, where the velocity in the pipe is low, it is necessary to accelerate it greatly in the throat in order to obtain sufficient loss of pressure and rise of float to secure reliable indications from the integrating drum. These cannot be obtained where the throat velocity is less than about 3 feet per second. With a throat ratio of 1 : 16, this would give a pipe velocity of $\frac{3}{16}$ foot per second. On the other hand, a meter with a high throat ratio, adapted to low velocities, would, with high velocities, exceed the upper limit of the integrating drum, which, as already mentioned, is arranged for a maximum throat velocity of 38 feet per second.

The manufacturers do not make a practice of selling Venturi meters less than 6-inch. Below that limit the cost of the register, which is a constant quantity, becomes relatively so great as to prevent successful competition with the ordinary mechanical meters.

The facility provided for the adjustment of the height of the integrating drum, while a very necessary provision, lays the device open to the manipulation of interested parties. It is desirable that this difficulty should be obviated.

It is also greatly to be desired that a continuously-recording register should be devised.

CONCLUSIONS.

Although the invention of Mr. Herschel and that of Messrs. Connet and Jackson have now been very prominently before the engineering profession for several years, your sub-committee is not aware that their claims of priority have been disputed. This, together with the granting of the patents in both cases, justifies us in regarding both inventions as new.

Differing radically in principle from all existing forms of meters, the Venturi is not a mere improvement upon them, but is a distinct innovation. It has also the very important advantage of being without any moving parts.

It is true that the ancient Romans used the Venturi mouthpiece as a means for defrauding the commonwealth, by taking, from the public pipes of distribution, more water than they were entitled to take, and that Venturi himself, a hundred years ago, used it as an ajutage in experiments for the purpose of obtaining a high coefficient of discharge through orifices ; but Mr. Herschel appears to be entitled to the honor of being the first to propose its use as a means of measuring the flow of water through pipes, by the use of piezometers, as herein explained.

Prior to its invention, there were no means for such measurement, except the weir and the measuring tank ; and in the great majority of cases it was out of the question to apply these means. The Pitot meter gives promise of usefulness in this connection, but it has not yet been so developed as to offer serious competition.

The Venturi meter, unlike the weir or the measuring tank, calls for no disturbance in the existing conditions, and it may be placed in the pipe at any convenient point. Its extreme simplicity and the entire absence of moving parts are scarcely less important advantages than the remarkable accuracy of its registration.

While the registering apparatus owes its existence to the Venturi tube, and is dependent upon it for its value, the tube, on the other hand, has a distinct and highly important value of its own, independently of the register, for, by the use of suitable pressure and vacuum gauges, the actual rate of discharge at any moment may be obtained with great accuracy.

For these reasons, we regard the Venturi meter tube as one of the most important of recent inventions, and we unhesitatingly recommend the award, to its inventor, Mr. Clemens Herschel, of the highest honor within the gift of the Institute—the Elliot-Cresson Gold Medal.

The highly ingenious and meritorious registering apparatus, invented by Messrs. Connet and Jackson, is entitled to the very important honor of having made the Venturi meter available for a host of purposes, for which, otherwise, it could not have been satisfactorily used. As now furnished with weight-driven mechanism, it gives excellent satisfaction, and, as one of our correspondents, already quoted, remarks: it gives no more trouble than any ordinary clock. The results obtained by its use appear to be as reliable as those obtained by extremely careful readings of mercury columns under favorable circumstances; with the additional and important advantage that it gives a cumulative record of the quantity discharged.

The device, however, like all others, has its limitations, some of which we have pointed out. It is as complex and delicate as the Venturi is simple and rugged. Whereas the tube, by its stoutness, seems almost to invite maltreatment, the register requires care to avoid damage, and skill to obtain the best results. Its cost is such as to prohibit the use of the combined device in the smaller sizes. Its record is not continuous. Its registration depends upon the assumption that the velocity has remained practically constant during the ten minutes elapsing between the times of tripping, or at least that the mean velocity during that period has been the same as at the moment of tripping.

Nevertheless, its invention, design and perfection are the fruits of great ingenuity and of much knowledge and painstaking labor, and they have been of vast benefit to the community by making, of the Venturi meter, a practical working tool.

Its inventors, Messrs. Frederick N. Connet and Walter W. Jackson, of Providence, R. I., are therefore entitled to distinguished honor at the hands of the Franklin Institute, and we take pleasure in recommending the award, to them, of the John Scott Legacy Premium and medal for their Registering apparatus.

Adopted at the special meeting of the Committee on Science and the Arts, held Wednesday, June 22, 1898.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
JAMES CHRISTIE,
Chairman Committee on Science and the Arts.

[The sub-committee which conducted this investigation was composed of Messrs. J. C. Trautwine, Jr., chairman, John E. Codman and Rudolph Hering.]

THE HYATT ROLLER BEARING.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of J. W. Hyatt, of Harrison, N. J.*]

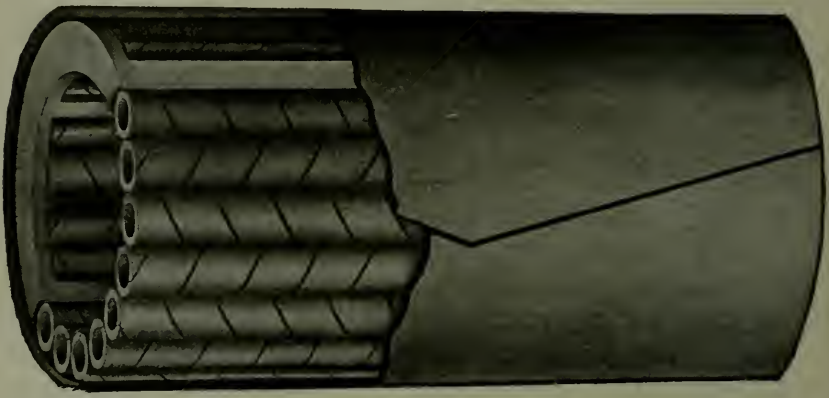
[No. 1880.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 22, 1898.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Hyatt's Roller Bearings, reports as follows:

The utility of anti-friction rollers is well known among mechanics, and they have been very extensively employed on many classes of machinery. Their advantages and the obstacles sometimes encountered in their use are so well known that it is unnecessary to enter into an explanation of the subject.

The sole innovation presented by the rollers of J. W. Hyatt, is the employment of an elastic, spirally-wound tubular roller, instead of the solid cylinder hitherto used. The mode of supporting the rollers, and the frames for confining them, are essentially identical with those long in use with the solid rollers.

The Hyatt roller, in appearance, resembles a closely wound spiral spring, made from a strip of steel of a rectangular section, and the roller consequently has all the flexibility of a similar spring.



Hyatt spiral roller bearing.

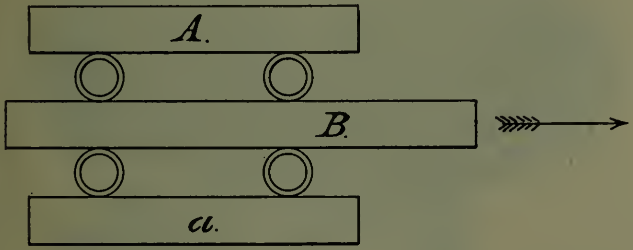
An experience of many years with anti-friction rollers by a member of this committee, and under many diverse conditions, justifies the assertion that one of the principal causes of failure on the part of anti-friction rollers which have been accurately made and well mounted, is due to an unequal distribution of pressure on the face of the rollers, causing distortion in detail or gradual destruction of the rollers. This inequality of pressure may be due to slight deflection of shafts, or yielding of supporting surfaces, or the axes of rollers and shafts may not be exactly parallel;

in fact, many different causes frequently act to prevent that perfect distribution of pressure over the whole length of the roller, which is essential to its longevity.

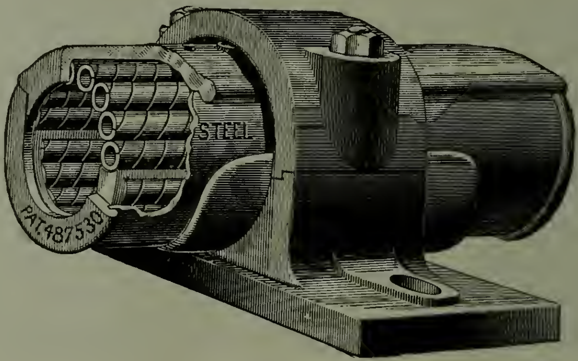
The pressure that rollers will safely endure depends on the diameter of the roller, on the hardness of the material in the rollers and of the surface they bear on, and also on the rapidity of the motion.

The endurance and frictional resistances of rollers under varying conditions of dimensions—material and speed—have been the subject of considerable experiment, which it is not necessary to quote further, as in this investigation the only question under consideration is the relative merits of the solid and the spiral formed roller.

In order to obtain experimental information on the subject, a series of experiments was made under several conditions, and the result of these experiments, which involved considerable time in the execution, are condensed into the attached table. Four of the Hyatt spiral rollers, and four solid steel rollers, all uniformly ¾ inch diameter and 10 inches long, were used in the tests. The Hyatt rollers were formed of strips of steel ½ inch wide and ⅛ inch thick, and were apparently of spring-steel, although we are informed that a softer grade of steel is used. The solid rollers were of a softer grade of steel, about 70,000 pounds tensile strength. The harder material in the spiral roller rendered it less liable to abrasion, but would not affect the resistance to rolling, so long as no abrasion occurred. These rollers were placed between three plates, as shown in sketch, and the whole set placed between the plates of a testing machine,



and vertical pressure applied. Whilst under this pressure a horizontal force was applied to the plate *B*, and the resistance to rolling accurately measured by its reaction on the platform of a scales. The faces of the plates *A* and *a* were planed, and in one series of experiments both faces of plate *B*. In the other series both faces of plate *B* were rough, that is, as they left the rolling mill. Increasing vertical pressures were applied, up to a maximum of 550 pounds per lineal inch of roller, when the apparatus employed would not permit a higher pressure, owing to the resistance to motion of the plate *B* when solid rollers were employed, but under the same conditions with the spiral rollers, it was possible to place a pressure per lineal inch of 700 pounds.



Hyatt spiral roller bearing applied to ball and socket pillow blocks with steel boxes.

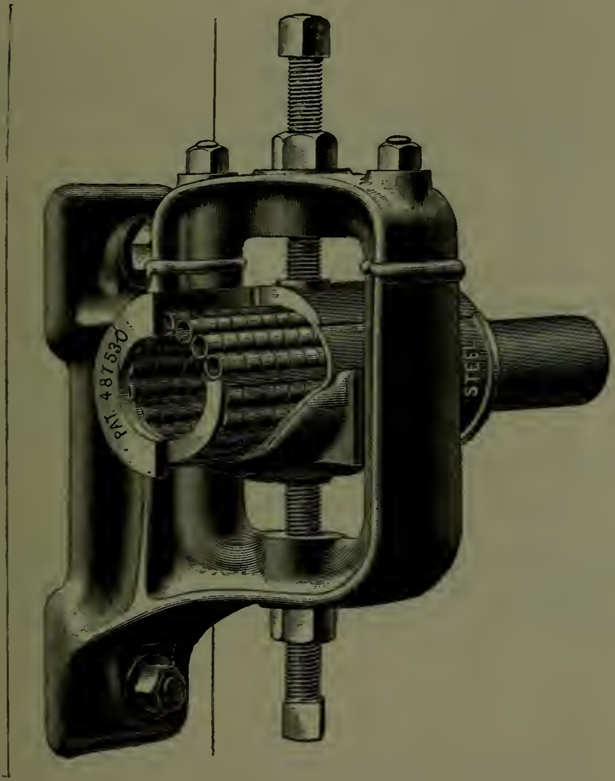
As the experiments were all made between the rigid plates of a machine in which the pressure was applied by screws, and registered on a scale beam, it was suspected that this rigidity might be more favorable to the spiral than to the solid roller. Therefore, an experiment was made in which the pressure was applied by a weight acting on a lever, and due to gravity only, with the following result:

Total Pressure Applied.	Resistance to motion of Plate B.	
	With Spiral Rollers.	With Solid Rollers.
2,000 pounds.	9 pounds.	26 pounds.
3,000 pounds.	17 pounds.	34 pounds.

These results correspond closely to the first experiments, and prove that the manner of applying pressure was not the cause of the difference in resistance to rolling.

It will be observed by the table that the resistance to motion was much less with the spiral than with the solid roller under all the pressures employed, both with the smooth and the rough center plate.

This reduction of rolling resistance varied from 10 to 66 per cent., and averaged 51 per cent. less with the smooth center plate, and 23 per cent. less with the rough center plate. Observations were likewise made to ascertain the thoroughness of the bearing contact between the plates and the rollers. With the rough center plate the incomplete bearing of the solid roller was plainly discernible, and under the maximum pressure employed, the solid roller showed indications of grooving at the point of contact, which is the usual manner of failure of anti-friction rollers. On the con-



Hyatt spiral roller bearing applied to post hanger.

trary, under the same conditions, the spiral rollers showed a complete bearing throughout their entire length, the elasticity of the roller permitting it to follow the sinuosities of the rough plate and maintain contact.

The pressures employed in the experiment were about as high as good practice tolerates with the slowest motion, and very much higher than is permissible with the velocities usual in ordinary shafting.

The spiral rollers are now regularly manufactured and successfully applied in practical use. The high pressure borne by the spiral roller without permanent deformation, its low resistance to motion as compared to the solid roller, and its elastic adaptation to inequalities of surface, were clearly exhibited by the experiments.

The Franklin Institute recommends the award to John W. Hyatt of the John Scott Legacy Premium and Medal, for his invention of the elastic spiral anti-friction roller.

Adopted at the special meeting of the Committee on Science and the Arts, held Wednesday, June 22, 1898.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

L. F. RONDINELLA,
Chairman Committee on Science and the Arts.

[The sub-committee which conducted this investigation was composed of James Christie, chairman, Hugo Bilgram, Spencer Fullerton, J. Sellers Bancroft, H. W. Spangler.]

APPENDIX.

COMPARISON OF SPIRAL AND SOLID ROLLERS.

Table No. I.

Total Pressure on Rollers. Pounds.	Pressure per linear inch of roll. Pounds.	Planed Plates.			Rough Plates (rolled).		
		Spiral Roller Coef. of Friction.	Solid Roller Coef. of Friction.	Ratio of Cols. 3 to 4 per cent.	Spiral Roller Coef. of Friction.	Solid Roller Coef. of Friction.	Ratio of Cols. 6 to 7 Per cent.
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1000	28	·005	·013	38	·018	·030	60
2000	55	·0055	·0125	44	·019	·026	73
3000	83	·005	·0116	43	·019	·021	90
4000	111	·0045	·012	38	·017	·021	81
5000	138	·004	·0116	34	·015	·022	68
6000	166	·0045	·0117	38	·016	·022	73
8000	221	·0056	·010	56	·017	·024	71
10000	277	·0063	·0113	56	·023	·026	88
12000	332	·0082	·018	46	·021	·028	75
14000	387	·012	·0195	61	·020	·029	69
16000	442	·014	·021	67	·024	·029	83
18000	498	·015	·024	62	·025	·029	86
20000	554	·016	·032	50	·029	·035	83
22000	609	·020			·031		
24000	664	·025			·033		
25000	700	·029			·034		

Percentage of coefs. of rolling friction of Spiral Rollers to Solid Rollers:

Plates Planed.		Plates Rough.	
Least	34 per cent.	Least	60 per cent.
Greatest	67 per cent.	Greatest	90 per cent.
Average . . .	48·7 per cent.	Average	77 per cent.

TEST OF HYATT SPIRAL AND SOLID STEEL ROLLERS.

TABLE II.

Total Pressure on Rollers in Pounds.	Pressure per Lineal Inch of Rollers in Pounds.	ALL PLATES PLANED.			
		"Hyatt" Spiral Roller.		Solid Roller.	
		Pounds to Move Plate "B."	Coeff. of Friction.	Pounds to Move Plate "B."	Coeff. of Friction.
1,000	28	5	·005	13	·013
2,000	55	11	·0055	25	·0125
3,000	83	15	·005	35	·0116
4,000	111	18	·0045	48	·012
5,000	138	20	·004	58	·0116
6,000	166	27	·0045	70	·0117
8,000	221	45	·0056	83	·010
10,000	277	63	·0063	113	·0113
12,000	332	98	·0082	213	·018
14,000	387	168	·012	273	·019
16,000	442	220	·014	334	·021
18,000	498	273	·015	438	·024
20,000	554	323	·016	638	·032
22,000	609	458	·020	Not Obtainable.	
24,000	664	555	·025		
25,200	700	739	·029		

PLATE "B." A ROLLED PLATE NOT PLANED.				Spiral Roller Deflection.	REMARKS.
"Hyatt" Spiral Roller.		Solid Roller.			
Pounds to Move Plate "B."	Coeff. of Friction.	Pounds to Move Plate "B."	Coeff. of Friction.		
18	·018	30	·030	.002	
38	·019	53	·026	·003	
58	·019	63	·021	·004	
73	·015	110	·022	·0055	The "Deflection" means the flattening or reduction of vertical diameter of the spiral roller.
99	·016	134	·022	·0055	
138	·017	194	·024	·006	
228	·023	260	·026	·006	
260	·022	338	·028	·006	
293	·021	412	·029	·006	
378	·024	463	·029	·006	
458	·025	518	·029	·006	
578	·029	708	·035	·006	
698	·031	Not Obtainable.		·006	
808	·033			·006	
878	·034			·006	

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

(For the year 1898.)

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts respectfully presents the following report of the operations of the Institute for the year 1898:

In reviewing the work for the past year, there is much to encourage, and the results achieved, taken in connection with the plans under consideration, should bring to the organization the aid of many not now connected with it. We have no greatly augmented membership or income to present, although there have been advances in both of these. Our strongest ground for mutual congratulation is in the activity of the various committees and sections, and in the general interest exhibited by members in advancing the usefulness of the Institute.

The changes in the building which were in progress at the time of the last report have been completed, and the bulk of our valuable Library is now placed on iron stacks, located in a portion of the building made perfectly fireproof. To make these changes required extra labor from the employés of the Institute, and the transfer and re-arrangement of the Library was tedious work, but the general satisfaction expressed at its consummation shows that the action is approved by the members of the Institute. Through the efforts of the Library Committee, many volumes were rebound, but the limitations of the available subscriptions prevented the completion of this desirable work.

The restoration of many interesting models, and their exhibition in cases has added interest to our building, and the conveniences of the Reading Room increase the attractive features.

The work of the various committees has been carried on with enthusiasm, and the interest in established sections has been unabated. The Mechanical and Engineering Section is a late addition, which gives promise of extended usefulness, and the creation of other sections now in contemplation, will probably soon give opportunity for extending the scientific activity of the Institute in other special lines.

During the year the Board gave a large portion of its meetings to discussing various plans for extending the usefulness of the Institute, and it is hoped that each member will feel the responsibility of assisting in carrying forward the plans adopted.

We are just closing the seventy-fifth year of the Institute's service in behalf of the promotion of manufactures and the mechanic arts, and no better celebration of this event could be suggested than the increase of our membership to a number sufficient to relieve the organization of the constant restrictions placed upon its expenditures, and to secure an endowment so ample as to permit of extending its work in the directions which are claiming its assistance.

Progress has been made in securing an endowment, and the Committee having this in charge is entitled to the hearty co-operation of all members and friends of the Institute. The field for usefulness is only partially covered, and the Franklin Institute cannot expect properly to occupy this field while its income is limited to an amount barely sufficient to carry on the work with economy, which by force of circumstances too often touches upon parsimony.

The Board hopes, with the co-operation of the members of the Institute, to so utilize our present restricted quarters as to ultimately command a more commodious and desirable building.

The following summary of the operation of the Institute, and of its committees and sections is respectfully submitted.

By order of the Board.

JOHN BIRKINBINE, *President.*

MEMBERS.

Members at the close of 1897	1,838	
Number of new members elected who have paid their dues in 1898	111	
		1,949
Lost by death, resignation and non-payment of dues,		99
Total membership at the end of 1898		1,850

FINANCIAL STATEMENT FOR THE YEAR 1898.

Balance on hand, January 1, 1898		$79 96
Receipts:		
*Committee on Publications	$2,870 73	
Committee on Library	28 97	
Committee on Instruction	895 00	
Committee on Science and the Arts	131 10	
Curators (old materials sold)	125 61	
Incidental Expenses (a reimbursement)	1 50	
Committee on Stocks and Finance	700 01	
Contributions for Life Memberships	400 00	
Contributions from Members, annual	5,638 00	
Entrance Fees of Non-Resident Members	160 00	
Certificates of Membership	1 00	
Insurances (rebate)	179 92	
M. Carey Lea Fund (income)	159 93	
Income Bloomfield Moore Fund	498 73	
Income from General Endowment Fund in hands of Trustees	1,921 24	
Loan on Mortgage from Board of Trustees	7,500 00	
Scott Legacy Premiums	200 00	
Sales of Index to *Journal of the Franklin Institute*	31 08	
Income B. H. Bartol Fund	50 00	
Carried forward		$79 96

Brought forward			$79 96
Income from Investments of Funds in the hands of Board of Managers		$795 00	
Proceeds of Sales of Central Railroad Co. of New Jersey Bond	$1,120 00		
Proceeds of Sales of Philadelphia & Reading Railroad 4 per cent. Bonds	5,183 75		
(Representing part of earnings of exhibition of 1874.)		6,303 75	
Income Memorial Library Fund		73 83	
Special Building Fund (donated)		955 00	
Sales of Exhibition Reports		7 40	
†Committee on Building Alterations		95 25	
Interest on bank deposits		35 51	
Committee on Endowment (donations toward expenses of committee)		179 73	
‡Donation of John G. Baker		750 00	
			30,688 29
Payments:			$30,768 25
Committee on Publications		$4,914 27	
Committee on Library		899 16	
Committee on Instruction		1,292 31	
Committee on Meetings		336 61	
Committee on Science and the Arts		197 43	
Curators		1,930 70	
Incidental Expenses		591 61	
Salaries and Wages		4,636 75	
Contributions for Life Memberships (paid to Board of Trustees)		400 00	
Certificates of Membership		25	
Insurances		596 92	
M. Carey Lea Fund Expenditures		103 18	
Special Building Fund		940 22	
Interest on Temporary Loans		403 24	
Interest on Mortgage Loan from Board of Trustees		168 75	
Scott Legacy Premiums		180 00	
Western Saving Fund Society (a deposit)		368 75	
Temporary Loan (paid off)		3,000 00	
Memorial Library Fund Expenditures		56 65	
Committee on Exhibitions		116 45	
Committee on Building Alterations		8,594 02	
Electrical Section		142 17	
Chemical Section		89 13	
Mining and Metallurgical Section		107 39	
Bloomfield Moore Fund Expenditures		312 17	
Committee on Endowment (expense account)		327 50	
			$30,705 63
Balance			$62 62

ENDOWMENT FUNDS.

The Permanent Endowment Funds of the Institute, at the end of 1898, consist of the following:

(In the hands of the Institute.)		
Bloomfield H. Moore Memorial Fund	$15,000 00	
Memorial Library Fund	1,000 00	
B. H. Bartol Fund	1,000 00	
Amount received from Life Memberships between January 1, 1891, and October 1, 1894	1,755 00	
		$18,755 00
(In the hands of Elliott-Cresson Trustees.)		
§The Elliott-Cresson Medal Fund (approximate)		4,729 55
(In the hands of the Board of Trustees of the Franklin Institute.)		
The legacy of George S. Pepper	$36,812 50	
The legacy of Eugene Nugent	1,000 00	
Legacy of Emeline B. Nicholson	1,520 00	
The Edward Longstreth Medal Fund	1,000 00	
The donation of an unknown friend	5 00	
The donation of Sigmund Riefler	20 00	
Life membership fund since October 1, 1894	1,450 00	
Journal Endowment Fund	138 00	
Special Endowment Fund	1,105 00	
By the will of John Turner, deceased, one-fourth of net income on 2 per cent. of his residuary estate, yielding about $100 or more per year, equivalent to a capital sum of	2,000 00	44,112 37
[An increase in 1898 of $2,691.87.]		$67,537 05

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* Credits other than cash to the account of Committee on Publications representing the value of exchanges, books reviewed and books purchased in exchange for advertising space, aggregated $1,565.96.

† The account of Committee on Building Alterations contains in its receipts donations made toward meeting its expenses:

From Messrs. Howson & Howson	$40 00	
From The Link-Belt Engineering Company	25 00	
		$65 00

‡ The donation of Mr. John G. Baker was made to aid in meeting such expenses as it might be found desirable to incur in adding to the comfort and attractiveness of the Reading Room, and $697.63 has been so expended under the direction of the Committee on Building Alterations.

§ Figures for 1898 are not at present accessible. Last year's amount is therefore substituted.

ANNUAL REPORT OF THE COMMITTEE ON INSTRUCTION, 1898.

To the Board of Managers.

GENTLEMEN:—The Committee on Instruction respectfully presents the following statement of its operations during the year 1898.

Lectures.—The Committee's tentative experiment in the year 1897, of arranging for the holding of certain lectures of a popular character in a larger hall than that of the Institute, proved so satisfactory, that the same plan was pursued during the past season, with results that have thus far been most gratifying. The Committee was thus enabled to accomplish the desirable objects of relieving the frequent overcrowding of the Lecture Room and of distinctly separating the popular lectures and strictly technical work.

By an arrangement with the Educational Committee of the Young Men's Christian Association, the popular lectures of the Institute were presented without additional expense to the Institute, in the large auditorium of Association Hall, at Fifteenth and Chestnut Streets, and were announced as a joint scientific lecture course under the patronage of the two societies. Members of the Institute and the Association were afforded special privileges in securing reserved seats at these events, so that all who chose to avail themselves of these opportunities were accommodated. This arrangement has worked to the mutual satisfaction of both societies. The cost to the Institute has been somewhat increased, but so slightly, that, when considered in relation to the advantages enjoyed by the members, it is not important enough to take into account. The Committee will use its best endeavors to make this arrangement, or one substantially like it, a continuing one.

The Committee was able last year, as hitherto, to secure the services of its eminent lecturers, without compensation, and would recommend to the Board a vote of thanks to these gentlemen, who have placed the Institute under substantial obligations.

Drawing-School.—The Committee is pleased to be able to report that the attendance of pupils in the Drawing-School during the past year exhibited an increase of over 10 per cent. as compared with the previous year.

Number of pupils in 1897	168
" " " " 1898	186
Increase	18

The attendance is still considerably below the record year, 1892, when it reached 295, but it is gratifying to be able to notice that the continuous falling off, which it has been compelled to report during the past three or four years, has been checked. The Germantown Junction Branch of the School exhibits a steady growth.

Mathematical School.—The Board authorized the Committee to proceed with the organization of a School of Elementary Mathematics. This was done, with the co-operation of Mr. Lucien Picolet, and the first season has been brought to a termination. Although the number of pupils was small, the Committee feels encouraged to proceed with the work, and expresses the hope that the next annual report will make a satisfactory exhibit of progress in this branch of work.

Respectfully submitted,

WM. H. WAHL, *Chairman.*

ANNUAL REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS, 1898.

To the Board of Managers.

GENTLEMEN:—The three Sections of the Institute, existing at your last annual meeting, continue their activity, and it is believed indicate a greater interest, and show more substantial progress this season than heretofore. The Mechanical and Engineering Section, which was authorized by your action of November 9, 1898, held a meeting for organization on December 15, at which time 74 persons attended; 158 names were enrolled as members, and the number has subsequently been increased to 166. The second Thursday of each month was adopted for the regular meeting of the Section, a Committee was appointed to nominate officers, and outline the work contemplated. Judging by the many expressions of approval, this Section promises to become one of the most popular and useful activities of the Institute, and opens a new field of usefulness for the Institute and the membership.

JAMES CHRISTIE, *Chairman.*

PHILADELPHIA, January 9, 1899.

COMMITTEE ON LIBRARY, ANNUAL REPORT FOR THE YEAR 1898.

To the President and Members of the Franklin Institute.

GENTLEMEN:—The Committee on Library respectfully reports the following summary of the operations of the Library during the year 1898:

F. LYNWOOD GARRISON, *Chairman.*

	Bd. Vols.	Unbd. Vols.	Pph.	Chts.	MSS.
Additions—By gift	582	278	1,081	3	
" to Mem'l Lib'y		3			
From Com. on Pub.	25	11	6		
Moore Fund	145	24	3		
Mem'l Library Fund		6			
General Fund			1	3	
Exchange	71	6	2	2	1
Added by binding	586				
	1,409	328	1,093	8	1

Total additions of all kinds	2,839
Total number of volumes at the close of 1898	48,769
Total number of (cataloged) pamphlets	33,546

The Library also contains 2,800 maps and charts, 641 designs and drawings, 1,222 photographs, 191 newspaper clippings, 26 manuscripts.

Binding—Reported, in additions, as new books	586	vols.
Unbound volumes taken from the shelves	148	"
Rebound	19	"
Memorial Library	25	"
Moore Fund	8	"
M. Carey Lea books (bequest)	102	"
Total number of volumes bound	888	

Exchanges.—Four hundred and fifty-nine societies and publications were on the exchange list of the JOURNAL at the close of the year, an increase of seventeen over 1897.

The Library was closed to the members from March 14th to April 16th, during which period the entire collection of books was dusted and removed to the shelves of the new steel stack in the fire-proof part of the building. This was a serious undertaking with the small force available for the purpose; the Librarian and his assistants deserve much credit for the care and expedition with which the work was carried out. As far as we now know, not a book or pamphlet of any value was lost or seriously injured, though in many instances old volumes were found in a very dirty and dilapidated condition—the result of many years of neglect or lack of means to properly care for our property.

It became evident that a great deal of binding was absolutely necessary, and efforts were therefore made to secure the requisite funds for the purpose, with the result that about $1,000 was subscribed, or about one-fourth of the amount required even with the utmost economy in its expenditure. This money was made to go as far as possible, but there yet remain several thousand volumes and periodicals urgently needing binding, besides hundreds of old volumes requiring re-binding.

The wear and tear upon the books will undoubtedly be much less in their present location than under the old arrangement.

The bound volumes and the patent specifications nearly fill the shelves of the stack, which was designed to hold from 50,000 to 60,000 volumes. It is doubtful if there yet remains sufficient shelf room to suffice for our accumulation of the next two years. As it is, our collection of pamphlets, maps, charts, etc., cannot be accommodated at all in the fire-proof structure, and as this is a very valuable part of the Library, some effort should be made to provide for their proper care.

Your Committee would recommend for that purpose the use of one of the two front rooms on the lower floor of the building. They are partially fire-proof, or, with trifling expense, can be made so, and your Committee feels that under the circumstances the present use of these rooms by the Institute is not consistent with the demands of our Library.

During the latter part of the year the card catalog has been completely changed, re-arranged and improved. The cards are now disposed of in the manner commonly followed in modern libraries; they cannot be taken from the drawers or disarranged by the users. The work of re-classifying the volumes has, of necessity, progressed very slowly during the year. It is being gradually accomplished.

Stored away in the third story are about 25,000 pamphlets awaiting classification and cataloging, hence at present useless to the members or to the public. The condition of this part of our Library is, to say the least, unfortunate; but it is impossible, with our inadequate staff, to undertake the work at present, and without a considerable expenditure the Committee has no hope of being able to do the necessary cataloging and classifying in the future.

As an indication of the great value of our Library collection, an incident which occurred but a few months ago, might be mentioned. The U. S. Navy Department, when in search of some old warship designs and plans, found that the only ones extant were at the Franklin Institute, and that a number of them were the originals. At the request of the department they were loaned and forwarded to Washington, that copies might be made. Your Committee finds that this invaluable collection of drawings and charts* is not even properly cataloged or listed, and not only in constant danger of destruction by fire in the present location outside of the fire-proof structure, but liable to danger from other agencies. New cabinets are urgently needed for their care, for which, together with the expense of mounting, cataloging, etc., about $500 will be required.

In the matter of purchasing books, the Committee has followed the usual practice of careful selection, making the purchases to fill the most important needs, yet distributing them to cover, as far as possible, the various branches of the Library; thus, for instance, our collection of chemical literature is exceptionally complete and comprehensive, hence an effort is always made to maintain it in this condition. Our photographic literature is also very comprehensive, and we will practically have little difficulty, thanks to the Lea bequest, in maintaining it up on this condition of completeness. Your Committee experiences less difficulty in making additions and maintaining the library abreast of the times, than in its general care and preservation. The funds appropriated by the Institute each year for this purpose, are entirely inadequate, whereas the income from the several specific bequests for the Library, must be spent for the purchase of books.

Your Committee has the satisfaction of being able to report that the use of the Library by the members exhibits a considerable increase. A careful investigation, however, of the attendance, has disclosed the fact that there is little or no use in keeping the Library open at night, as heretofore. It is a useless and unwarranted expense, and will therefore be discontinued from and after February 1, in accordance with the following regulations:

1st. On Saturdays the Library will close at 5 o'clock P.M., excepting that during the summer season the regulations at present in force shall continue.

2d. On all other days of the week, namely, from Monday to Friday, inclusive, the Library will be closed at 8.30 P.M., excepting on the evening of the stated meeting of the Institute (the third Wednesday of each month), when the present arrangement to close at 10 o'clock P.M., will remain in force.

On the whole, although the general condition of the Library is far from what it should be, it is in a much better condition than ever before.

ANNUAL REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS, 1898.

The President and Members of the Franklin Institute.

GENTLEMEN:—The Committee on Science and the Arts respectfully submits the following report of its operations for the year 1898, giving the details of the number and character of applications received and considered and of action had upon them, and of its accounts, in an appendix hereto.

These show that the number of applications for investigations received, and of cases referred by the Institute or approved by the Committee, was 59, slightly above that of the preceding year.

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* The gift of John Lenthall, deceased, late Naval Constructor, U. S. N.

The number of cases in which reports were made, or which were otherwise disposed of, was 47, which is somewhat less than that of the preceding year.

There have been awarded and recommended, of Elliott Cresson Medals, 2; of John Scott Legacy Premiums and Medals, 6; of Edward Longstreth Medals, 2, and of Certificates of Merit, 2. There have been made 9 reports without awards, and 7 advisory reports, and 3 reports on special subjects.

As this Committee may recommend annually many more than the above number of awards, several different efforts have been made during the year to bring a larger number of apparently meritorious inventions before the Committee. The most recent of these, and the one that promises to be most permanently successful, is the appointment by the Committee of a special committee of its members, to discover and recommend suitable subjects for investigation. The members of the Institute are again requested to co-operate in this respect.

The Committee hereby expresses its appreciation of the valuable service rendered by several members of the Institute who assisted in the work of its sub-committees. Very respectfully,

L. F. RONDINELLA,
Chairman Committee on Science and the Arts.

(Adopted at the Stated Meeting held Wednesday, January 4, 1899.)

ANNUAL REPORT OF THE COMMITTEE ON MEETINGS FOR THE YEAR 1898.

To the President and Members of the Franklin Institute.

GENTLEMEN:—The Committee held ten stated meetings during the year, and arranged for the presentation of twenty-six papers and communications, a number of which will be found printed, at length, in the *Journal*. The general standard of these contributions has been high, and the attendance at the meetings of the Institute exhibited an increasing interest in these events among the members.

Respectfully submitted, on behalf of the Committee.

WASHINGTON JONES, *Chairman.*

PHILADELPHIA, January 1, 1899.

REPORT OF THE COMMITTEE ON CABINET OF MODELS FOR THE YEAR 1898.

To the President and Members of the Franklin Institute.

GENTLEMEN:—The Committee on Cabinet of Models reports further progress made during the past year, in connection with the revision of the collection of models.

The work of selecting for preservation, the models of value and interest, and disposing of the others, has been completed; and the enumeration, labeling and display of those retained is steadily going forward under the Committee's general direction. Already the most valuable of these have been arranged and attractively displayed in the Reading Room, and some of the larger ones in the vestibule. The work will be entirely finished early in the present year.

HENRY HOWSON, *Chairman.*

PHILADELPHIA, January 1, 1899.

ANNUAL REPORT OF THE CHEMICAL SECTION, 1898.

To the Committee on Sectional Arrangements.

GENTLEMEN:—I have the honor of submitting herewith my annual report as President of the Chemical Section for the year 1898.

Meetings of the Chemical Section have been held regularly during the year, except in the months of June, July and August. At most of these meetings, the attendance was very good, and at some numbered more than a hundred.

The present membership of the Section is 95.

So active has the Committee on Papers and Communications been, since the fall of the year, that it has become necessary, besides the regular stated meetings to hold special meetings.

The number of communications which they have secured is still so large, that it will probably necessitate the holding of special meetings during the remainder of the season. At the date of writing, the committee is in possession of fourteen papers, which have been promised for presentation before the Section.

During the past year, the following communications, lectures and addresses were presented at the various meetings.

Prof. William C. Day. "Action of Carbon Dioxide on Sodium Aluminate and the Formation of Basic Aluminum Carbonate."

Prof. F. A. Genth. "The Detection of Salicylic Acid."

Mr. Edward H. Earnshaw. "The Chemical Composition and Technical Analysis of Water Gas."

Mr. G. M. Eldridge. "A Method of Applying a Money Standard to the Nutritive Values of Feeding Stuffs."

Mr. Paul R. Heyl. "On a Supposed Change of Weight with Change of Temperature."

Mr. A. Hamburger. "Recent Developments in the Textile Industries."

Prof. William C. Day. "A Method of Analyzing Commercial Phosphorus."

Dr. Robert H. Bradbury. "On Chemical Equilibrium."

Dr. Harry F. Keller. "The Synthetic Preparation of Organic Hydroxy-acids."

Prof. William C. Day. "The Synthesis of Gilsonite."

Mr. Hudson Maxim. "Modern High Explosives and Smokeless Powders, and Their Application in Warfare."

Mr. Charles A. Hexamer. "Chemical Fire Extinguishers."

Dr. William H. Wahl. "An Improved Artificial Stone."

Dr. Harvey W. Wiley. "The Agricultural Possibilities of our New Possessions."

Prof. C. B. Cochran. "Butter and Butter Fats."

Dr. Robert H. Bradbury. "Reaction Velocity."

Dr. Henry Leffmann. "Digestive Ferments with Especial Reference to the Effects of Food Preservatives."

Mr. Lyman F. Kebler. "Bébées."

Mr. Lyman F. Kebler. "Notes on Estimating Eucalyptol."

Dr. W. J. Williams. "Methods for Examination of Explosives."

The Section, as will be perceived from this brief summary of its activity fully maintained its reputation as a live working branch of the Institute, and its future prospects were never more satisfactory.

Respectfully submitted,

LEE K. FRANKEL, *President.*

PHILADELPHIA, January 1, 1899.

REPORT OF THE MINING AND METALLURGICAL SECTION FOR THE YEAR 1898.

To the Committee on Sectional Arrangements.

GENTLEMEN :—The Mining and Metallurgical Section of the Franklin Institute presents the following report of its operations during the year 1898:

Membership.—The accessions to membership during the year were seven. Total membership, December 31, 1898, seventy-seven.

Meetings.—The Section held twelve meetings during the year, of which one was a joint meeting with the Numismatic and Antiquarian Society.

General Remarks.—The extended discussion which several of the papers read at the meetings called forth, affords the best evidence that could be desired of the live interest taken by the members, and the safest guaranty of its continued activity as a useful branch of the Institute. Nearly all the papers enumerated below, with the discussions thereon, have been deemed sufficiently meritorious to be published in the *Journal.*

The activity of the Committee on Papers, and its successful efforts in filling the program of the Section meetings, for practically the entire season, with interesting and important communications, have been most commendable, and have fully justified the expectations of the founders of the Section. that it could be made a center from which most valuable work would emanate. The Section appears now to be firmly established, and its future career promises well for the Institute.

In taking a brief retrospective view of progress in mining and metallurgical industries of the United States, and of the world as well, during the past few years, it becomes apparent that this Section of the Institute was inaugurated at an opportune moment.

Phenomenal activity prevails in nearly all branches of mining and metallurgy, while the recent production of crude material has not only surpassed all former records, but has exceeded all expectations and astonished the whole world.

An official report of the "Mineral Products of the United States," for the calendar years 1888 to 1897, inclusive, recently issued by the United States Geological Survey, shows that the production of gold from the mines of the United States increased from 1,604,927 troy ounces, having a coining value of $33,175,000, in 1888, to 2,774,933 troy ounces in 1897, having a coinage value of $57,363,000. The production of silver increased from 45,783,632 troy ounces in 1888, having coining value of $59,195,000, to 53,860,000 troy ounces in 1897, having coining value of $69,637,172; the production of copper increased from 231,270,622 pounds in 1888, to 491,638,000 pounds in 1897; the production of lead increased from 131,919 tons in 1888, to 208,192 tons in 1897; the production of zinc increased from 55,903 tons in 1888, to 99,980 tons in 1897.

The most remarkable increase in production, however, is found in the metal aluminum, of which 19,000 pounds were produced in 1888, and 4,000,000 in 1897.

In the list of non-metallic mineral products, given in the official report herein quoted, similar gains are recorded in many instances. The output of petroleum, for example, increased from 27,612,025 barrels in 1888, to 60,586,081 barrels in 1897. The production of bituminous coal increased from 102,039,838 short tons in 1888, to 147,789,902 short tons in 1897. The anthracite coal production of Pennsylvania in 1888 amounted to 41,624,611 long tons, and in 1897 to 46,814,074 long tons.

Improved mining and metallurgical methods have practically created value in many low grade ores which could not be profitably worked under old methods. The cyanide process for recovering gold from tailings and from lean ores of certain kinds, is not yet ten years old in its practical application to gold mining, yet it is stated that one-third of the gold of the South African field is now obtained by this process.

The United States, by reason of its recently acquired supremacy in the production of iron and steel in all forms, has now taken a leading industrial position among the great nations of the world, and the proceedings of the various technical societies—of which the Franklin Institute is one of the most venerable and most highly respected, both at home and abroad—attract world-wide attention.

For these and other reasons it may be confidently expected that the future career of the Mining and Metallurgical Section of the Franklin Institute will be one of continued expansion and usefulness.

A. E. OUTERBRIDGE, JR., *President.*

PHILADELPHIA, January 1, 1899.

APPENDIX.

The following list embraces the authors and titles of the papers and communications presented before the Section during the past year:

Pedro G. Salom. "The Electrolytic Production of Lead from Galena."

Benj. S. Lyman. "Some Illustrations of the Influence of Geological Structure on Topography."

Paul Kreuzpointner. "The Practical Aspects of Present Commercial Methods of Testing Iron and Steel."

Capt. E. L. Zalinski, U. S. A. "Japanese Swords."

Robert W. Lesley. "Development of the American Portland Cement Industry."

Prof. Alexis A. Julien. "Building Stones; Elements of Strength in their Constitution and Structure."

Raimundo Cabrera. "The Mineral Resources of Cuba."

Miltiades Th. Armas. "Reduction Works for Silver Ores at Aduana, Sonora, Mexico."

Wm. Tatham. "Gold Mining in Georgia."

G. H. Clamer. "The Microstructure of Bearing Metals."

Wm. Griffith. "Anthracite Coal in Peru."

A. E. Outerbridge, Jr. "The Mining and Minting of Gold and Silver."

A. E. Outerbridge, Jr. "A Study of the Micro-Structure of Bronzes."

Wm. R. Webster. "Specifications on Structural Steel and Rails."

Prof. H. C. Mercer. "Fresh Studies of Pioneer Tools."

Prof. T. C. Hopkins. "The Feldspars and Kaolins of Southeastern Pennsylvania.

ANNUAL REPORT OF THE ELECTRICAL SECTION FOR THE YEAR 1898.

To the Committee on Sectional Arrangements.

GENTLEMEN:

Officers.—The business of the Section has been conducted by the following officers:

President, Mr. Walter E. Harrington.
Vice-President, Mr. G. U. G. Holman.
" " Mr. Thomas Spencer (resigned May 2, 1898).
Secretary, Mr. J. A. LaFore (resigned January 8, 1898).
" Mr. Wm. Warr (resigned August 3, 1898).

At this writing no Secretary is in office.

Membership.—The membership at the beginning of the year was 105. At the present date the number of members is 116, including all names which have been dropped from the roll. This is an increase of nine members over last year.

Meetings.—The regular monthly meetings were held during the year, at which the average attendance was fifteen; this is a decrease over the preceding year.

Papers (read in 1898):

Mr. David Pepper. "Line and Return Circuit Construction of Electric Rugs."

Mr. Herbert Laws Webb. "The Telephone Exchange."

Prof. Arthur Goodspeed. "Recent Advances in Radiography.

Discussion.—Rail Bonding. Opened by Mr. Walter E. Harrington.

Mr. Wm. A. Rosenbaum. "The Status of Electrical Invention."

Mr. J. H. Cook. "The Jenkins Improved Lamp Holders for Incandescent Lamps."

Mr. A. J. Wurts. "Lightning and Lightning Arrestors."

Mr. C. J. Reed. "Thermo-Electricity."

Prof. Chas. F. Marvin. "The Kite as an Instrument in Meteorological Research."

Prof. Arthur J. Rowland. "Photometers and Electric Light Photometry."

Papers (to be read):

Mr. W. B. Tapley. "The Practical Application of the Electric Motor to Printing Press Machinery."

Mr. Albert B. Herrick. "The Electric Inspection of Street Car Equipments."

Mr. Edward E. Higgins. "Some of the Larger Transportation Problems in Cities."

Mr. B. C. Washington. "Water-Power Electric Plants in the United States."

Prof. Reginald A. Fessenden. "Electro-Magnetic Mechanism, Design of, with Especial Reference to High-Frequency Telegraphic Receivers."

Mr. James Hamblet. "Electrical Clocks Historically Considered, with a Description of the most Successful Applications of Electricity to Clocks, and the Uniform Distribution of Time."

Mr. A. Langstaff. Subject to be announced.

Mr. E. G. Acheson. "Recent Developments in the Manufacture and Application of Carborundum."

Mr. F. B. Badt. Some theme in connection with the progress of electro-metallurgy.

Mr. W. J. Hammer. Subject to be announced.

Mr. J. D. Darling. "The New Harrison Cell."

Mr. J. Appleton. "Recent Developments in the Application of the Storage Battery."

Mr. W. E. Harrington. "Rail Bonding, with Special Reference to Cast Weld Joints."

Outlook.—The outlook for next year is encouraging. There has been an increase of membership of men who are successful in conducting scientific bodies and with the program that has been arranged the results realized should be very good. Respectfully submitted,

W. E. Harrington, *President.*

Philadelphia, January 1, 1899.

NOTES AND COMMENTS.

KITES AS INSTRUMENTS OF METEOROLOGICAL RESEARCH.

At the last meeting of the Royal Meteorological Society in London, Mr. A. L. Rotch read a paper on the exploration of the free air by means of kites, referring more particularly to the experiments lately made at the Blue Hill Observatory, Massachusetts. Of this paper the London *Nature* gives the following abstract:

"After giving a brief account of the use of kites for scientific purposes from 1749 to the present time, the author describes the various forms of kites which have been employed at Blue Hill Observatory, viz., the Eddy, or Malay tailless kite; the Hargrave cellular or box kite; and the Lamson acro-curve kite. The highest flight was on October 15, 1897, when, by means of four kites having a combined lifting surface of 150 square feet, the meteorograph at the end of 20,100 feet of wire, was raised vertically 11,080 feet above the hill. About 200 records from kites have been obtained in the free air at heights from 100 to 11,000 feet in all kinds of weather. Mr. Rotch maintains that the kite can be made of the greatest importance for meteorological investigation. At the recent meeting of the International Aëronautical Committee at Strasburg, it was recommended that all central observatories should employ kites as being of prime importance for the advancement of meteorological knowledge."

In connection with the recent revival of interest in the kite as an instrument in meteorological research, it may be noted that fifty years or more ago there existed in Philadelphia a local "Kite Society" for this very purpose. The activity of this body in its observations of the height of clouds and other interesting meteorological facts is attested by the fact that some of its work is quoted with approbation by Espy in his epoch-making book on storms. It is no less curious than regrettable that all traces of this society have apparently been lost. The most diligent efforts to find its records, if any were kept, have been fruitless of result. W.

NEW USE FOR CALCIUM CARBIDE.

Aside from its use for generating acetylene gas for illuminating purposes, this substance has properties that may render it valuable for other industrial purposes. Borchers, in Germany, has proposed its use for deoxidizing and carbonizing steel, for which purpose the analogous silicon carbide has been successfully employed in this country, and Caro suggests its use for the production of cyanides by heating it in a current of nitrogen and steam. If this last proposition should prove practicable on the commercial scale, it would prove highly important in view of the large and constantly growing demand for cyanides in extracting gold from low-grade ores. W.

VACUUM DRYING.

The English electrical journals briefly describe an apparatus said to be quite widely used by the leading electrical firms of Germany for the drying of the insulation of electrical coils, dynamo armatures, etc., at low temperatures by means of a vacuum. The apparatus consists simply of a cast-iron chamber closed by doors hermetically sealed with India-rubber gaskets, and arrangements for obtaining a vacuum of 28 inches of mercury or more, and for heating the chamber proper by steam or hot water. At a very moderate temperature, about 95° F., water evaporates more rapidly under this condition than at temperatures under atmospheric pressure high enough to injure the insulating properties of organic substances through carbonization. With a high vacuum it is stated that materials can be thoroughly dried at as low a temperature as 63° F. It is said that English cable works have used a similar process for jute and paper insulated cables as well as washed India-rubber for some time. W.

IMPROVED ELECTRIC INCANDESCENT LIGHT.

Nernst, a well-known German electrician, has patented an improvemen in electrical glow lights which consists in the use of a cylinder of magnesia, or similar substance, which possesses the property of being a non-conductor of electricity when cold, and of becoming conductive when heated to a high temperature. These cylinders are provided with electrical connections, and means—such as a Bunsen burner—are used to heat them to the conductive temperature, when the current alone will maintain them in incandescence.
W.

NEW USES FOR GLASS.

Experiments have lately been made with glass as a substitute for metals for bearings. The most suitable kinds were found to be bottle and ordinary window glass. The bearings were cast in moulds, in two pieces. They gave the best results when mounted in elastic supports. It was found to be necessary that the revolving parts should be well balanced and the shafts accurately centered. The results are stated to have been that the glass bearings require less lubrication, have less friction, and in many cases are more advantageous than metal bearings, though in some cases they afford less security than others.

It is recorded in the French journal, *L'Eclairage Electrique*, that at Marseilles, glass tubes are being used as underground conduits for telegraph wires and for carrying electric-light wires in factories, theatres, etc. W.

ASPHALT JOINTS FOR GLAZED STONEWARE (TERRA-COTTA) PIPES.

In Germany, it is said, asphalt joints for terra-cotta pipes are now used in all the chief cities. The melted asphalt is poured around the socket end of the pipes when the two ends had been brought together. On testing such joints by hydraulic pressure, the pipes were found to give way before the joints showed any signs of leaking. W.

NICKEL-STEEL FOR MARINE BOILERS AND ENGINES.

The latest applications of nickel-steel are in connection with marine boilers and engines. This alloy is found to be much superior to other kinds of steel for marine boiler plates on account of its greater resistance to the corrosive action of salt water. It is also found to be excellently adapted on account of its great toughness for parts of marine engines, especially for the hollow shafts used on the latest transatlantic steamers. W.

COSMIC DUST IN HAIL.

Professor Karpinsky, a well-known Russian savant, recently made an interesting communication to the St. Petersburg Academy on a fall of hail observed on April 30, 1897, by M. Czernik, near Ivangorod, in Russian Poland.

The following account of the occurrence is taken from London *Nature*:

The hail was falling that day from two nearly opposite directions, and was of two entirely different kinds. One variety consisted of large grains of pear shape, and of a peculiar structure; while the other consisted of smaller, transparent grains, which had the shape of flattened ellipsoids. These latter contained nothing, but the former had in their central opaque portions black granules, which proved, on chemical analysis, to consist of iron, with traces of nickel and cobalt, and silicon. These granules were sent to the Academy, and Professor Karpinsky analyzed them. The powder obtained from these granules consisted chiefly of magnetic iron oxide, which had been formed through the oxidation of metallic iron; the latter could be seen very well. Moreover, the granules contained augite and, probably, sulphuretted iron, and some other substances not yet determined. Besides iron, they also showed traces of nickel and sulphur. "Such a composition," the Russian professor concludes, "leaves not the slightest doubt about the cosmic origin of the granules contained in that hail." It is interesting to note that, some time ago, M. Czernik collected at the same spot hail which contained granules of volcanic ashes from Vesuvius. W.

EXTREMELY ANCIENT MIRRORS.

At one of the recent sessions of the French Academy, Berthelot described three metal-backed glass mirrors of great antiquity which had been originally discovered in Thrace and Egypt. The metal backing of these mirrors consists of almost pure lead, which, in the molten state, appears to have been poured on the concave surface of disks cut from balloons of blown glass. This appears to be a highly important contribution to the history of the arts among the ancients. W.

IGNITING COMPOSITION FOR A SELF-LIGHTING GAS-BURNER.

A recent German patent describes in the following terms the preparation of a gas-igniting composition for the automatic lighting of gas-burners. Very porous carbon (charcoal or coke?) is submitted at a high temperature to the action of chlorine vapors, then thoroughly purified by washing. The mass is now saturated with a solution of palladium chloride, and heated in a current of hydrogen gas, whereby the palladium is reduced to the metallic state, and disseminated in the pores of the carbon in a state of extremely fine division. W.

A NOVEL PROPOSITION FOR REACHING THE NORTH POLE.

Admiral Makaroff, the well-known Russian explorer of the North Pacific Ocean, has lately made the interesting and novel suggestion to reach the North Pole by means of powerful ice-breaking vessels. London *Nature* gives the following account of his proposition :

"The proposal sounds rather strange at first, but the Russian Admiral bases it on sound scientific reasoning and on a good deal of actual experience. Ice-breakers have been used in Russia (at Cronstadt) since 1864, and lately great progress was achieved in their construction in America by arming such vessels with two screws at the stern and a third one at the stem. The American ice-breaker, 'Ste. Marie,' 3,000 horse-power, easily sails through ice 2½ feet thick, and pierces ice-walls 15 feet high. Still more powerful ice-breakers have lately been built in America and in this country for the Trans-Siberian railway and the port of Vladivostok. Taking into account that, according to Nansen, the ice-walls (*toroses*) in the Arctic basin seldom attain the height of 25 feet, and that the polar sea is free from ice over, at least, one-third of its surface, while all the ice is weakened in summer by thawing, and especially by interior canals due to accumulations of salt, and by crevices, Admiral Makaroff concludes that an ice-breaking steamer of 20,000 horse-power would overcome all the difficulties which polar ice may oppose to her progress. The distance between the latitude of 78° N. to the pole being 720 miles, he calculates the various speeds at which such a steamer could make her way through ice of various thicknesses from four to seven feet, and he finds that the total distance could be covered in twelve days. Moreover, instead of one ice-breaker of 20,000 horse-power, it would be advantageous to have two such vessels of 10,000 horse-power each, it having lately been proved by actual experiment in Russia that two ice-breakers placed one behind the other, and the rear one pushing the front one by means of a special wooden frame, act as effectively as one single ice-breaker of a double force. Admiral Makaroff's propcsal is, therefore, to build two special ice-breakers of 6,000 tons and 10,000 horse-power each, provided with stem screws, and to force a way through the ice to the pole." W.

GERMAN TECHNICAL SCHOOLS.

Of the extension of technical education Germany has always been the most prominent exponent. Writing on this subject, a European contemporary says: The whole German people are being educated scientifically in the arts of industrial production. Nowhere in the world does manufacturing become so nearly a profession as in Saxony, for in this small kingdom there are no less than 111 technical institutes; Prussia has 200 such schools, with only 12,000 pupils; thirty-five of the schools are for painters and decorators, sixteen for tailors, nine for shoemakers, etc., other trades having at least one school. The Government appropriates $600,000 annually for their support and the various towns and cities give liberal subsidies, Berlin alone giving $70,000 per annum. Baden, with 1,600,000 inhabitants, spends $280,000 a year on technical schools. Hesse, with a population of 1,000,000 has eighty-three schools of design, forty-three of manufacturing industries and many others for artisans of various trades. W.

LIGHTING THE PYRAMIDS BY ELECTRICITY.

Engineering News refers to a plan now under consideration by the British Government for the lighting of the pyramids by electricity, and the installation of an electric power transmission plant of 25,000 horse-power.

The plan involves the erection of a power generating plant at the Assouan Falls on the river Nile, and its transmission over a distance of 100 miles through the cotton-growing districts, where, it is thought, the provision of cheap power from this source, will permit the building of cotton factories. Part of the scheme contemplates the lighting, from this source, of the interior corridors of the pyramids, and also the operation of pumping machinery for irrigating large areas of desert lands along the Nile. It is also stated by the *News*, than an American company is likely to receive the contract for this work. W.

IRON-NICKEL ALLOY FOR INCANDESCENT ELECTRIC LAMPS.

The so-called leading-in wires for attaching the carbon filament and making electric connections, have thus far been made of platinum. This appears to be the only metal which has the same rate of expansion and contraction as glass, and its use for this purpose has consequently been compulsory with the manufacturers of electric incandescent lamps, since by no other means has it been found possible to avoid leakage of air into the interior of the bulb and the speedy destruction of the filament.

From experiments lately conducted at one of the Reichanstalten in Germany, on nickel-iron alloys, it has been developed that the coefficient of expansion of such alloys varies according to the percentages of the two metals present. Furthermore, it is said to have been experimentally demonstrated that an alloy of iron and nickel containing 45 per cent. of nickel possesses the same rate of expansion as platinum, and it is proposed to use this alloy to replace platinum in the manufacture of incandescent electric lamps. W.

HARDENING ARTICLES OF PLASTER-OF-PARIS.

A German patent has been granted for the treatment of articles of plaster-of-Paris with an aqueous solution of ammonium borate for the purpose of hardening them and rendering them insoluble in water. A simple and efficient process for accomplishing this object would be highly desirable, as it would serve to greatly prolong the life of plaster casts, which being quite soft and not entirely insoluble, sooner or later become superficially defaced, and washing speedily wears down the outlines of the object.

The process above referred to is said to give results decidedly superior to anything that has heretofore been proposed. The hardening liquid may either be mingled with the plaster in the act of moulding, or it may be applied on the surface of the finished casts with a brush.

The solution is prepared by dissolving boracic acid in warm water, and adding thereto sufficient ammonia to form the borate, which remains in solution.

The manner of using the solution is thus described:

The saturation of the gypsum or painting of the plaster-of-Paris articles is carried out in the cold. The objects are subsequently rinsed off and dried. The surface becomes very hard after two days and insoluble in water, while the induration in the interior advances more slowly. By means of the fluid described gypsum floors can be hardened and rendered more durable and impervious to the influence of the weather. Saturating with ammonium borate is said to be especially useful on exterior walls of buildings, barracks, etc., on the latter, because experiments have proved an antiseptic action of the liquid. W.

Franklin Institute.

[*Proceedings of the annual meeting held Wednesday, January 18, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 18, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 162 members and visitors.

Additions to membership since last report, 43.

The President presented some remarks, *apropos* to the near approach of the seventy-fifth anniversary of the Institute, which are reproduced elsewhere.

The annual reports of the Board of Managers, of the various Standing Committees and Sections, and of the Trustees of the Cresson Medal Fund, were presented and accepted. (These reports are printed in this impression of the *Journal.*)

The Actuary reported the following resolution in reference to the hours of closing the Library in the evening, adopted by the Board of Managers, on the recommendation of the Curators and Committee on Library, at its stated meeting of January 11th, inst., viz.:

"(1) On Saturdays the Library will close at 5 P.M., excepting that, during the summer season, the regulations at present in force shall continue.

"(2) On all other days of the week, namely, from Monday to Friday, inclusive, the Library will be closed at 8.30 P.M., excepting on the evening of the stated meeting of the Institute (the third Wednesday of each month), when the present arrangement to close at 10 P.M. shall remain in force."

The Board has directed that these rules shall be enforced on and after February 1, 1899.

The Secretary reported a recommendation of the Mining and Metallurgical Section, that the Institute, as a body, should become a member of the American Branch of the International Association for Testing Technical Materials. In connection with this recommendation, the Secretary presented and read the following communication from Mr. Wm. R. Webster, member of the Section, strongly urging the desirability and advantage of co-operation by the Institute in the work of the Association, viz.:

"PHILADELPHIA, January 18, 1899.

"*Dr. Wm. H. Wahl, Secretary Franklin Institute.*

"DEAR SIR:—I * * * desire to call your attention to the importance of the Franklin Institute becoming a member of the American Branch of the International Association for the Testing of Materials. The Institute could be of the greatest service in collecting specifications from our engineers, manufacturers and railroads, as their request for them would be promptly complied with. This work is absolutely necessary as a preliminary step in arriving at what would represent standard American specifications of to-day for each class of material. Similar work will have to be done in each country, and then the four or five standard specifications compared, as the first step towards international specifications.

"A full set of American specifications collected in this way would be a valuable addition to our library, and of considerable benefit to our members, and especially to our engineers and manufacturers. Yours truly,

"Wm. R. Webster."

The recommendation was, on motion, approved, and the matter was referred to the Mining and Metallurgical Section, with authority to take all needful steps to make the co-operation of the Institute in the work of the International Association effective.

The President introduced the speaker of the evening, Prof. Raoul Pictet, of Geneva, Switzerland, who addressed the meeting on the "Influence of Extremely Low Temperatures in Chemistry, and on the Application of the Low Temperatures in Establishing New Methods of Chemical Synthesis." Professor Pictet illustrated his theme by a number of striking experiments, showing the arrestation of chemical action at temperatures approximating — 80° C. Thus, at or about this temperature metallic sodium and hydrochloric acid do not react; hydrochloric acid is inert in presence of fragments of marble; litmus tincture has lost its sensitiveness as an indicator of acids and alkalies, etc., etc.

[The paper was referred for publication.]

The meeting tendered the speaker a vote of thanks for his extremely instructive address.

The Secretary presented and commented upon a number of technical topics.

The tellers of the annual election presented their report, which was accepted, and they were discharged, with the thanks of the Institute for their services. The President thereupon declared the following persons to have been elected:

For President	(to serve one year), ...	JOHN BIRKINBINE.
" *Vice-President*	(" three years), ...	CHAS. BULLOCK.
" *Secretary*	(" one year), ...	WM. H. WAHL.
" *Treasurer*	(" one year), ...	SAMUEL SARTAIN.
" *Auditor*	(" three years), ...	WM. H. GREENE.

For *Managers* (to serve three years).

THOS. P. CONARD,
JAMES M. DODGE,
C. LELAND HARRISON,
WASHINGTON JONES,
ISAAC NORRIS, JR.,
STACY REEVES,
FRANCIS SCHUMANN,
COLEMAN SELLERS.

For the *Committee on Science and the Arts* (to serve three years).

HUGO BILGRAM,
FRANK P. BROWN,
J. J. DEKINDER,
W. C. L. EGLIN,
A. M. GREENE, JR.,
FRED. E. IVES,
CHAS. JAMES,
W. N. JENNINGS.
ARTHUR KITSON,
WILFRED LEWIS,
EDGAR MARBURG,
C. J. REED,
E. ALEX. SCOTT,
COLEMAN SELLERS,
H. W. SPANGLER.

To fill the unexpired term of Clayton W. Pike, resigned, FRANCIS HEAD.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held January 4, 1899.*]

PROF. L. F. RONDINELLA in the Chair.

Reports on the following subjects were considered :

Universal Trimming Shear.—Reinhold Bettermann, Johnstown, Pa. Referred back to Sub-Committee for amendment.

Marine Steam Boiler.—Edward J. Moore, Philadelphia.

The following were adopted :

Steel Freight Car Truck.—Frederick S. Owen, Waltham, Mass.

ABSTRACT.—This invention relates to a metal truck for railway cars, which is claimed to furnish a better truck than the "arch-bar" truck in general use, and which is constructed partly of metal and partly of wood.

The sides are composed of panels, preferably of pressed steel, having inwardly turned flanges. Adjoining the flanges are pedestals formed of U section bars, which are bent to the shape of an inverted ∩, the top of which reaches flush with the top of flange of panel, the ends of the downwardly extending legs projecting below the flange of the panel.

The center of the truck is formed of a plate of pressed steel, properly fastened to the transoms, and supported by a transverse tie. There are also transverse ties at each end of the truck, which tie the ends of the frames outside of the pedestals, to afford sufficient strength to resist shocks from side strains and also to provide means to hang brake-beams.

(The invention is protected by U. S. letters-patent, No. 578,579, March 9, 1897, to applicant.)

The report finds that nearly all the claims, ten in number, are for some form of flanging or bending the material of which the truck is made. None of them, however, in the Committee's opinion, is a substantial improvement on other methods of doing this work, and the combination evidences nothing not already in use in metal car trucks, and which, while in no respects inferior to this one, can be made more cheaply. [*Sub-Committee.*—Henry F. Colvin, Chas. C. H. Downs, Calvin G. Turner.]

Combination Cartridge-Loading Tool.—Gideon S. Adams, Camden, N. J.

ABSTRACT.—These tools consist of two metal jaws of peculiar shape, pivoted to each other, and of two small separate tools to be inserted, when required, in the ends of the jaws. One of these is used in decapping shells, and the other in crimping them. The metal jaws and their permanent attachments enable the operator to cut and trim, cap, ram the wads into and crease the shells. The jaws can also be used to pull shells from the gun, to replace pincers and to unscrew nuts.

(The invention is protected by letters-patent of the United States, No. 428,328, May 20, 1890, granted to applicant.)

The report finds that these tools have the merit of lightness and compactness claimed for them, and that all the operations of loading and unloading No. 10 or No. 12 shot-gun shells can be performed by them.

The Committee is of opinion, however, that this work can be done better and more quickly with separate tools, specially adapted to the principal operations; and that only under exceptional circumstances would it be to the advantage of the average gunner to use the Adams tools. [*Sub-Committee.*—B. W. Dunn, Chas. T. Carpenter Smith, J. Logan Fitts.]

Window-Blind Lock. G. O. Brosnahan, Jr., Pensacola, Fla.

ABSTRACT.—The applicant has endeavored to provide a fastening for window-blinds, which shall be more difficult to open from the outside than those in common use.

The device consists essentially of two bolts, one for each shutter, each contained in a suitable metal casing, with a coiled spiral spring around the bolt, arranged to throw it partially out of its cylindrical casing. The lock cases are let into the widow-sill directly under where the blind rests when closed, so that the bolt will project above the level of the sill. A keeper-plate is let into the bottom edges of the blind, so that when the blind is drawn in for closing, it first depresses the bolt (which is beveled for the purpose), and allows it to rise into the socket of the keeper-plate, thus locking the blind. A steel wire rod, bent to proper shape, is attached to the bottom end of each of the bolts so as to pass obliquely downward and connects with a foot-press projecting through the baseboard on the interior of the room. These rods are flattened near their ends, and perforated to allow of adjustment to different heights of window-sills.

When the blinds are drawn inward until shut, they are locked. By pressing with the toe of the shoe against the projecting foot-press, the bolts are withdrawn and the blinds are unlocked. To prevent an intruder from the outside from working the foot-press, by removing several slats, and using a stick to press down the foot-press, a catch is provided which must first be thrown sideways before the foot-press can be depressed.

The lock has evidently been planned for use mainly in houses built of wood, where there is plenty of room for arranging the connecting rods between the outer weather-boarding and the inner plastering.

The Committee believes that while the device has the merit of novelty, its value is not such as to induce its use to any extent as a substitute for other less expensive and more easily placed appliances for accomplishing the same result. No model was submitted. [*Sub-Committee.*—Stacy Reeves, Chairman; Samuel Sartain.]

Inertia Indicator.—Wilfred Lewis, Philadelphia.

ABSTRACT.—This instrument was designed by applicant for the determination of the inertia of a traveling crane in starting and stopping, in order to design the side-bracing for the runways.

The report is reserved for publication in full. The Edward Longstreth Medal of Merit is awarded to applicant for his successful application of the principle of the level lathe to the determination of inertia. [*Sub-Committee.*—Arthur M. Greene, Jr., Edgar Marburg, Hugo Bilgram, Luigi d'Auria.]

Check-Punch.—G. O. Brosnahan, Jr., Pensacola, Fla. (A re-investigation. See the *Journal* **145**, 475.)

In the previous report it was understood by the investigating committee that the machine printed the figures upon the paper, in imitation of the usual perforations. It now appears that the machine is a perforator. No model was submitted. The report finds that while the invention is ingenious, the machine will be far more costly than those at present in use, doing better work. Report made advisory and approved. [*Sub-Committee.*—Edward F. Moody, Chairman.]

Steam Trap.—Antoine Heintz, Liège, Belgium. A re-investigation, on a protest submitted by the inventor against the conclusions of previous report. (See the *Journal*, **146**, 79, to which also reference is made for a description of the apparatus and its *modus operandi.*)

The present report after rehearsing the description and operative data of the previous report, proceeds to state that while the trap has been found, under the Committee's observation, to work with entire satisfaction, "under both medium and low pressures," it has been found "under high pressures, to work unsatisfactorily, the valve being cut and a length of pipe being necessary to cool the water to a temperature at which the trap is operative. This * * * means the loss of heat and consequently excessive condensation, which should not be in a good trap. The trap will not relieve a sudden rush of hot water."

Respecting the question of originality of invention, which formed the ground for the protest of Mr. Heintz against the previous report, the investigating committee, to which evidence was submitted by Mr. Heintz, of priority of invention over Mr. Alfred Peyer, finds said evidence to be inconclusive. [*Sub-Committee.*—Arthur M. Greene, Jr., Henry F. Colvin, Robt. D. Kinney, J. M. Emanuel, U. S. N.]

The Omnimeter.—Albert Sexton, Philadelphia.

ABSTRACT.—This apparatus is a form of calculating instrument, or slide-rule, embracing all mathematical operations usually performed with the aid of tables of logarithms and of trigonometrical functions, thus including the arithmetical processes, exclusive of addition and subtraction.

The instrument is composed of two circular discs and a radial runner movable about a common center. The outer disc is about six inches in diameter. Several forms of the instrument are made; one, notably, with a single disc is devoted entirely to numbers arranged progressively in ten circles. This is called the "Companion to the Omnimeter." The material of the discs is a species of indurated fiber, which in addition to being quite durable is not affected appreciably by moisture.

(An intelligible description of the instrument without a sketch cannot be made.)

The investigating committee commends the care and skill of applicant in producing so accurate and reliable an instrument. The report finds that Mr. Sexton's contribution to the development of mechanical computers is of such value as to entitle him to the award of the John Scott Legacy Premium and Medal, which is accordingly recommended. [*Sub-Committee.*—Wilfred Lewis, Chas. H. Suplee, A. E. Outerbridge, Jr., Wm. H. Thorne.]

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CHEMICAL SECTION.

Stated Meeting, January 17, 1899.

THE CLARIFICATION OF RIVER WATERS.

BY ALLEN HAZEN.

It is an old saying that mortals care more for their worldly goods than for their spiritual welfare. It is equally true that people care more for the appearance of the water which they drink than they do for its healthfulness.

One reason for this may be that appearance is, in a measure, an indication of quality, and an indication which everyone can apply for himself; and there may be an element of vanity which leads us to put the qualities which we can note for ourselves above those which we cannot see, and which we only know about through the reports of others, of the exact value of which we allow ourselves to be a little skeptical. At any rate, clear water is only second in importance to wholesome water, and is worth all the effort that is necessary to secure it.

The ideal water in appearance is distilled water, which is perfectly clear and limpid, and has a slight blue color. When other waters are compared with it, the divergences in color from the color of distilled water are measured, and not the absolute colors of the waters. Many spring waters and filtered waters are indistinguishable in appearance from distilled water.

Public water supplies taken from rivers contain two substances or classes of substances which injure their appearance, namely, peaty coloring matters and mud. Waters discolored by peaty matters are most common in New England and in certain parts of the Northwest, while muddy waters are found almost everywhere, but of different degrees of muddiness, according to the physical conditions of the water-sheds from which they are obtained.

Muddy waters are often spoken of as colored waters, and in a sense this is correct where the mud consists of clays or other materials having distinct colors; but it is more convenient to classify impurities of this kind as turbidities only, and to limit the term colored waters to those waters containing in solution vegetable matters which color them.

The removal of either color or turbidity may be called clarification.

Colored waters are usually drawn from water-sheds where the underlying rock is hard and does not rapidly disintegrate, and where the soils are firm and sandy; and especially from swamps. The water here comes in contact with peat or muck, which colors it, but is so firm as not to be washed by flood-flows, and so does not cause turbidity.

Large parts of the United States have for rock foundations shales or other soft materials which readily disintegrate when exposed, and which form clayey soils readily washed by hard rains. Waters from such water-sheds are generally turbid and very rarely colored. In fact, a water carrying much clay in suspension is usually found colorless when the clay is removed, even if it were originally colored. It thus happens that waters which are colored and turbid at the same time hardly exist in nature.

Color-producing matters and turbidity-producing matters are different in their natures, and the methods which must be adopted to remove them are different. I shall speak to you to-night only of the removal of turbidity.

But first let us consider how water becomes turbid. Consider, if you please, a plowed field of clayey soil, or such a field upon which crops are growing. If it has not rained for some days, and the surface-soil is comparatively dry, the first rain that falls upon it is absorbed by the pores of the soil until they are filled. If the rain is not heavy, but little runs off over the surface. If, however, the rain continues rapidly after the surface-soil is saturated, the excess runs off over the surface to the nearest water-course. The impact of the rain-drops upon the soil loosens its particles, and the water flowing off carries some of them in suspension, and the water is said to be muddy.

The particles carried off in this way are extremely small. Mr. George W. Fuller, in his report upon water purification at Louisville, estimates that many of them are not more than $\frac{1}{100000}$ of an inch in diameter, or not more than $\frac{1}{10}$ as large as the common water bacteria. These particles, and larger ones, may sometimes be present in water to such an extent as to form more than $\frac{1}{1000}$ of its weight.

The amount of mud in a water is often expressed as the proportion of suspended matters referred to the weight of the water. This method of statement does not altogether meet with our requirements, because it fails to take into account the different sizes of the particles which are carried in suspension by different waters, and at different times. The Merrimac River in a great flood may carry 1 part in 1,000 of fine sand in suspension, and still it could hardly be called muddy; while another stream carrying only a fraction of this amount of fine clay would be extremely muddy. Further, an accurate determination of suspended matters is a somewhat troublesome and tedious operation, and cannot be undertaken as frequently as is necessary for an adequate study of the mud question.

Turbidity is principally important as it affects the appearance of water, and it would seem that optical rather than gravimetric methods should be used for its determination. The literature of engineering contains descriptions of numerous appliances, more or less elaborate, for measuring the obstruction to light of given depths of waters. Some of these methods, theoretically most perfect, are too complicated for general use.

Some years ago, while making experiments at Lawrence for the Massachusetts State Board of Health, I found it necessary to have a method of expressing the turbidities of various waters, and I adopted the very simple device of sticking a pin into a stick and pushing it down into the water under examination as far as the pin could be seen and measuring the depth. Afterward a platinum wire, 0·04 of an inch in diameter, was substituted for the pin, and the stick was graduated so that the turbidities could be read off directly. The figures on the stick are inversely proportional to their distances from the wire. When the wire can be seen 1 inch below the surface, the turbidity is 1·00; when the wire can be seen 2 inches, the turbidity is 0·50; when it can be seen 10 inches, the turbidity is 0·10, etc. This scale is much more convenient than a scale showing only the depth at which the wire can be seen; and within certain limits the figures obtained by it are directly proportional to the amount of the elements which obstruct light in the water. Thus, if a water having a turbidity of 1·00 is mixed with an equal volume of clear water, the mixture will have a turbidity of 0·50. This procedure is used for the determination of turbidities so great that they cannot be conveniently read by direct observation.

For the greatest accuracy it is necessary that the observations should be taken in the open air and not under a roof. They should preferably be made in the middle of the day, when the light is strongest, and in case the sun is shining the wire must be kept in shadow and not in direct sunlight.

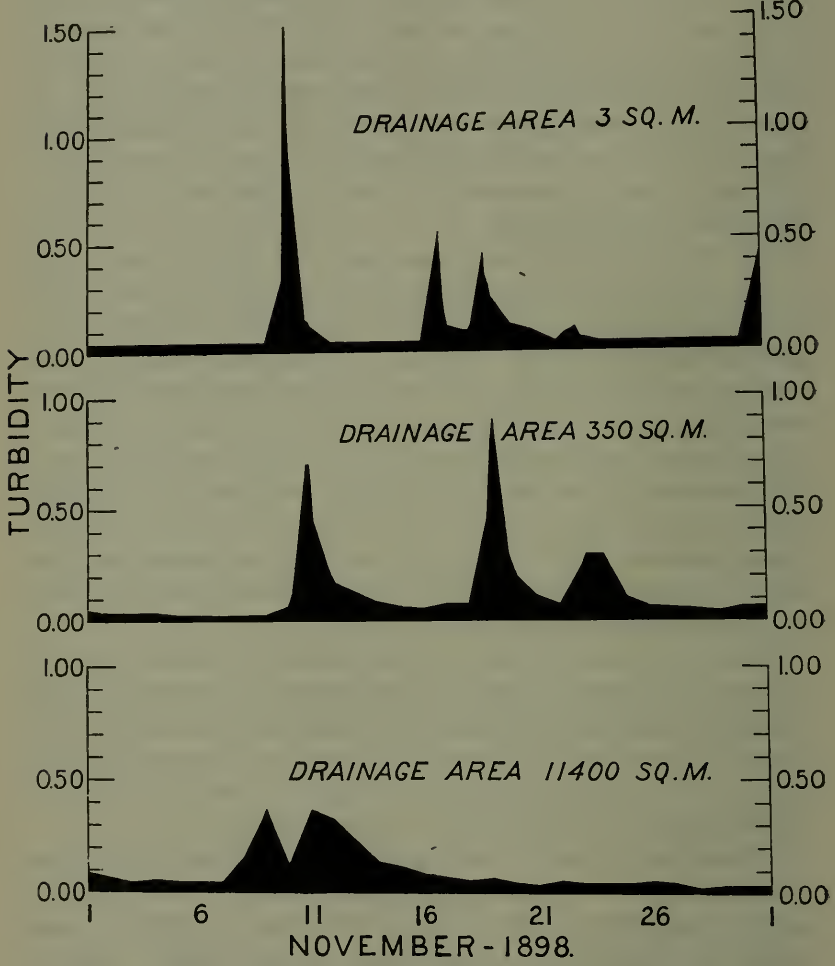
The method thus developed has been used in a number of cases with most satisfactory results. If it lacks something in theoretical accuracy as compared with more elaborate methods, it more than makes up for it by its simplicity and general adaptability to all sorts of conditions. Reliable observations can be taken by people who would be entirely incompetent to use more elaborate apparatus, and its application is thereby greatly extended.

Having now a scale with which to measure the turbidities of waters, let us turn again to the water flowing from our plowed field. It has perhaps a turbidity of 2·00, that is to say, the wire is hidden by a depth of ½ inch of water. When it reaches the nearest water-course it meets with water from other kinds of land, such as woodlands and grassed fields, and these waters are less turbid. The water in the first little water-course is thus a mixture and has a turbidity of perhaps 1·00.

The conditions which control the turbidity of any brook are numerous and complicated. The turbidity of a stream receiving various brooks depends upon the turbidities of all the waters coming into it. Generally speaking, the turbidity of a river depends directly upon the turbidities of its feeders, and is not affected materially either by erosion of its bed or by sedimentation in it. There are, of course, some streams which in times of great floods cut their banks, and all streams pick up and move about from place to place more or less of the sand and other coarse materials upon their bottoms. The materials thus moved, however, have but little influence upon the turbidity.

After the rain is over some of the water held by the soil will find its way to the water-courses by underground channels, and will prevent the stream from drying up between rains, but the average volume of the stream-flows between the rains will be much less than the volumes during the rains when the water is most turbid.

These conditions are well illustrated by a few data upon the turbidity of three Pennsylvania streams, which I have recently collected. One of these streams is a small brook having a drainage area of less than 3 square miles. The observations extend over a period of forty-seven days. During this time there were five floods, or an average of one flood in ten days. The duration of floods was less than twenty-four hours in each case. Selecting the days when the turbidity was highest, to the number of one-tenth of the whole number of days, the sum of the turbidities for these days was 67 per cent. of the aggregate turbidities for the whole period. That is to say, 67 per cent. of the whole amount of mud was in the water of only a tenth of the days, the other nine-tenths of the days containing only 33 per cent. of the whole amount of turbidity. The average turbidity of the water



Turbidities of three Pennsylvania streams of different sizes during November, 1898.

for the flood days was 18 times as great as the average turbidity for the remaining days.

The next stream is a considerable creek having a drainage area of 350 square miles. The observations extended over 117 days, during which time there were seven floods, or an average of one flood in nineteen days. The floods lasted in each case one or two days, and the sum of the turbidities for the one-tenth of the whole number of days when the water was muddiest was 55 per cent. of the aggregate of all the turbidities for the period.

The last set of observations is for a large river, with a drainage area of over 11,000 square miles, and extends over a full year. In this period there were sixteen floods, each lasting from one to six days, and the sum of the turbidities for the one-tenth of the whole number of days when the water was muddiest is 45 per cent. of the aggregate turbidities for the year. The floods occurred on an average of once in twenty-two days, and the average duration was two and one-half days.

The results are very striking as showing that a very large proportion of the mud is carried by the water in flood-flows of comparatively short duration. They also show that in small streams the proportion of mud in the flood-flows is greater and the average duration of floods is shorter than in larger streams. In other words, the differences between flood- and low-water flows are greatest in small streams, and gradually become less as the size of the stream increases.

When a stream is used for water-works purposes in the usual way, a certain quantity of water is taken from the stream each day, which quantity is nearly constant, and is not dependent upon the condition of the stream or of the volume of its flow. The proportions of the total flows taken at high- and low-water stages are very different, and it thus happens that the average quality of the water taken for water-works purposes is different from the average quality of all the water flowing in the stream.

Let us assume, for example, a stream having a watershed of such a size that in time of moderate floods water from the most distant points reaches the water-works intake in twenty-four hours. Let us assume further that rain-falls of sufficient intensity to cause floods and muddy water occur, on an average, once in ten days, and that the turbidity of the water at these times reaches 1·00, and that for the rest of the time the turbidity averages 0·10. Let us assume further that at times of storms the average flow of the stream is 100 units of volume, and for the nine days between storms the average flow is 10 units of volume. We shall then have in a ten days' period, for one day, 100 volumes of water with a turbidity of 1·00, and nine days with 10 volumes each, or a total of 90 volumes of water, with a turbidity of 0·10. The total discharge of the stream will then be 190 volumes, and the average turbidity 0·57. The turbidity of 0·57 represents the average turbidity of all the water flowing in the stream, or, in other words, the turbidity which would be found in a lake if all the water for ten days should flow into it and become thoroughly mixed without other change.

Now let us compute the average turbidity of the water taken from the stream for water-works purposes. The water-works require, let us say, 1 volume each day, and we have for the first day water with a turbidity of 1·00, and then for nine days water with a turbidity of 0·10. The average turbidity of the water taken by the water-works for the period is thus only 0·19 in place of 0·57, the average turbidity of the whole run-off.

The water flowing in the stream is thus just three times as turbid as the water taken from the stream for water-works purposes.

It is often noted that with long streams the water becomes muddier further down, and it may naturally be thought that it is because of the added erosion of the stream upon its bed in its longer course. This, of course, may be a cause, or the lower tributaries may be muddier than the upper ones, but the fact that the water taken at the lower place is more muddy than further up is not an indication of this.

Let us take, for example, a water-shed of twice the size of that assumed above; that is, so long that forty-eight hours will be required for the water from the most remote feeders to reach the water-works intake. Let us divide this shed into two parts, which we will assume to be equal, one of which furnishes water reaching the intake within twenty-four hours, and the other water reaching the intake between twenty-four and forty-eight hours. Now suppose a storm upon the water-shed producing turbidities equal to those just assumed for the smaller stream. On the first day the water from the lower half of the shed, namely, 100 volumes having a turbidity of 1·00, passes the intake, but this is mixed with 10 volumes of water from the upper half of the water-shed having a turbidity of 0·10, and the total flow is thus 110 volumes of water having a turbidity of 0·92. On the second day the water from the lower half of the water-shed has returned to its normal condition, and the flood-flow of the upper half of the water-shed, 100 volumes with a turbidity of 1·00, is passing and mingles with the 10 volumes from the lower half with a turbidity of 0·10, and the total flow is again 110 volumes having a turbidity of 0·92. The following eight days, until the next rain, will have flows of 20 volumes each with turbidities of 0·10. The average turbidity of all the water flowing off is 0·57, as before, but the water taken for water-works purposes will consist of 2 volumes of water with turbidities of 0·92, and 8 volumes with turbidities of 0·10, making an average turbidity of 0·26.

By doubling the length of the water-shed we have thus doubled the length of time during which the water is turbid, and have increased the average turbidity of the water taken for water-works purposes from 0·19 to 0·26, although the average turbidity of all the water running off remains exactly the same.

If now we assume a water-shed so long that three days are required for the water from the most remote points to reach the intake, with computations as above, water taken for water-works purposes will have an average turbidity of 0·32; and with still longer water sheds this amount will increase, until with a water-shed so long that ten days are required for the water from the upper section to reach the intake, and the average turbidity of the water taken for water-works purposes will reach the average turbidity of the run-off, namely, 0·57.

In the above computations the numbers taken are round ones, and, of course, would not represent actual conditions. They do serve, however, to illustrate clearly the principle that the larger the water-shed, other things being equal, the more muddy will be the water obtained from it for water-works purposes, and the longer will be the periods of muddy water, and the shorter the periods of clear water between them.

It cannot be too strongly emphasized that the period of duration of muddy water is dependent upon the length of time necessary for the muddy water to run out of the stream system after it is once in it, and be replaced by clear water; and that the settling out of the mud in the river has nothing to do with it. The absence of deposits of the fine clay which is so freely carried by flood-flows is the best evidence of the lack of sedimentation in Pennsylvania streams.

Muddy waters are principally the results of rains upon the surface of ground capable of being washed, and the turbidity of the stream at any point below will occur at the times when the muddy water reaches it in the natural course of flow, and will disappear again when the muddy water present in the stream system at the end of the rain has run out, and has been replaced with clear water from underground sources, or from clearer surface sources.

Having now considered briefly the causes of turbidities in streams, and the circumstances which control their duration, let us consider the measures which can be taken for reducing or removing them from public water supplies.

We have first the use of reservoirs. Reservoirs serve two purposes in connection with water drawn from streams; they allow sedimentation, and they afford storage. If a water having a turbidity of 1·00 is allowed to remain in a sedimentation basin for twenty-four hours, the turbidity may be reduced by as much as 40 per cent., or to 0·60. If it is held a second day the additional reduction is much less.

If samples are taken of the water in the reservoir before and after settling and sent to the chemist for analysis, he will probably report that from 70 to 80 per cent. of the suspended matters have been removed by the process. The suspended matters are removed in much larger ratio than the turbidity. This arises from the fact that there is a certain proportion of comparatively coarse material in the water as it is taken from the river. This coarse material increases the weight of the suspended matters without increasing the turbidity in corresponding degree. In twenty-four hours the coarser materials are removed completely, and at the end of that time only the clayey or finer particles remain in suspension. It is these clayey particles, however, that constitute the turbidity which is most objectionable in appearance, and which is most difficult of removal by filtration or otherwise.

After the water has settled for twenty-four hours, if the figure representing the turbidity is multiplied by 16 it will express approximately the weight of the suspended matters remaining in the water, in parts per 100,000. With the water as it is taken from the river, it is necessary to use a larger factor for this purpose, factors of 30, 50 and even 100 being required, according to the character of the suspended matters.

Sedimentation thus removes the heavier matters from the water, but it does not remove the finer matters which principally affect the appearance of the water, and are otherwise more troublesome. A sedimentation of twenty-four hours removes practically all of the coarser matters, and the clayey material remaining at the end of that time can hardly be removed by further sedimentation. The economical limit of sedimentation is about twenty-four hours.

Sedimentation has practically no effect upon the clearer waters between flood periods.

Let us now consider the effect of a sedimentation basin or reservoir holding a twenty-four hours' supply of water, into which water is constantly pumped at one end and constantly withdrawn from the other, upon the water of a stream of such size that the time of passage from the feeders to the intake is less than twenty-four hours. During the period between storms the water is comparatively clear and passes through the sedimentation basin without change. When a storm comes the water in the stream promptly becomes muddy, and muddy water is supplied to the reservoir; but, owing to the time required for water to pass through it, the outflowing water remains clear for some hours. There is a gradual mixing, however, and, long before the expiration of twenty-four hours, somewhat muddy water appears at the outlet. The turbid water period rarely lasts in streams of this size more than twenty-four hours, and at the expiration of that time the water in the sedimentation basin is as muddy or muddier than the water flowing in the stream. After the height of the flood the stream clears itself by the flowing away of the turbid water much more rapidly than the water clears itself by sedimentation in the reservoir. That is to say, if at the time of maximum turbidity we take a certain quantity of water from the stream and put it aside to settle, at no time will the improvement by settling equal the improvement which has taken place in the stream from natural causes. Generally, the improvement in the stream is several times as rapid as in the sedimentation basin, and the water from it will at times have only a fraction of the turbidity of the water in the basin.

Let us now consider what the sedimentation has done during our assumed ten-day period. For eight days of clear water it has done nothing. For the day of the flood very much clearer water has been obtained from it than was flowing in the stream. For the day following the flood the water in the sedimentation basin has been more muddy than the water in the stream. The only time when the sedimentation basin has been of use is during the first part of the flood, that is, the part in which the turbidity of the water in the stream is increasing. During this period it has been of service principally because of its storage capacity, yielding up water received from the stream previously, when it was less muddy. Such sedimentation as has been secured is merely incidental and not important in amount.

It will be obvious from the above that for these conditions storage is much more important than sedimentation. This brings us back to the old English idea of having storage reservoirs large enough to carry water-works over flood periods without the use of flood waters. Reservoirs of this kind were, and still are considered necessary for the successful utilization of waters of many English rivers, although these waters do not approach in turbidity the waters of some American streams. This idea of storage has been but little used in the United States.

In the above case, if we use our reservoir for storage instead of as a sedimentation basin, the average quality of the water can be greatly improved. The reservoir should be kept full during clear-water periods, and pumping to it should be stopped whenever the turbidity exceeds a certain limit, to be determined by experience, and the reservoir is then to be drawn upon for the supply until the turbidity again falls to the normal. In the case assumed above, with a stream in which all of the water reaches the intake in twenty-four hours, a reservoir holding a twenty-four hours' supply, or in practice, to be safe, a somewhat larger one, would yield a water having an average turbidity of only 0·10 as against an average turbidity of 0·19 for water pumped constantly from the stream without a reservoir.

With a river having a water-shed so long that forty-eight hours are required to bring the water down, a reservoir twice as large would result in a reduction of the average turbidity from 0·26 to 0·10, an improvement absolutely impossible with sedimentation alone.

As the stream becomes larger and the turbid periods longer, the size of a reservoir necessary to utilize this action rapidly becomes larger, and the times during which it can be filled are shortened, and thus the engineering difficulties of the problem are increased. For moderately short streams, cost for cost, storage is far more effective than sedimentation, and we must come back to the old English practice of stopping our pumps during periods of maximum turbidity.

Neither storage nor sedimentation is capable of adequately removing mud from water. The process can only be finished by filtration. Two methods of filtration have been extensively used for this purpose. These are known as sand and mechanical filtration. They differ principally in that the rate of filtration with mechanical filtration is many times greater, and that the process is assisted by the use of coagulant, which forms a flocculent precipitate in the water, which draws the particles of sediment together and allows them to be more readily removed by filtration.

With either sand or mechanical filtration the difficulty in treatment, as I shall show, increases nearly in direct proportion to the turbidity, and it is thus highly important to secure a water for filtration with as little turbidity as possible, and thus to develop to their economical limits the preliminary processes of storage and sedimentation.

Let us consider the nature of the agencies which in filtration lead to the removal of turbidity. First there is the straining action, which consists in stopping particles too large to go through the passages in the filter. Straining is an important element in filtration, but it is never adequate in itself. If the passages of a filter are made so small as to stop even tolerably well the finest particles of sediment, they are so small as to make it impracticable to get adequate quantities of water through them. Any filter which acts as a strainer only can remove only the larger particles, and not the smaller ones, which so largely constitute the turbidity.

The next agency of importance in the work is adhesion. When the particles of suspended matters are carried into contact with the filtering material, many of them get close enough to it to adhere to it and remain fixed while the water flows on without them. Closely connected with adhesion, but differing from it, is, third, sedimentation taking place in the pores of the filter. In the removal of suspended matters from water by sedimentation, we may assume that owing to its weight and the viscosity of the water, each particle will make a certain rate of progress downward through the water. With the smaller particles this rate of progress is extremely slow, and with a sedimentation basin several feet deep many days may be required for a particle to reach the bottom, and in fact its progress may be entirely offset by currents in the sedimentation basin, resulting from the action of the wind or from temperature changes, which constantly mix the water up from top to bottom and absolutely prevent the deposit of the finest particles. With a sedimentation basin that is not so deep, the improvement in a given time becomes greater, owing to the shorter courses for the particles. If it is filled with coarse gravel or other loose material through which the water very slowly flows, particles have to settle only to the first stone or other obstruction with which they come in contact, and the lengths of the courses of the particles are greatly reduced and the improvement correspondingly increased. It thus happens that by putting water through even quite a coarse material, so coarse that no straining whatever can be conceived as taking place in it, the improvement in its appearance may nevertheless be quite marked.

In a filter the conditions for sedimentation are still further greatly improved. The spaces between the sand grains are extremely small, and the course of a particle from any point in the interstices to the sand grains next below is very short, and when a particle strikes bottom it is perhaps assisted in remaining there by adhesion, especially where the grains of filter sand have accumulated organic growths more or less sticky in their natures. Sedimentation in the filter beds thus becomes an important factor in clarification.

It is essential for these processes that the rate of filtration shall not be so great as to sweep the particles forward when they come in contact with particles of the filtering material instead of allowing them to remain upon them.

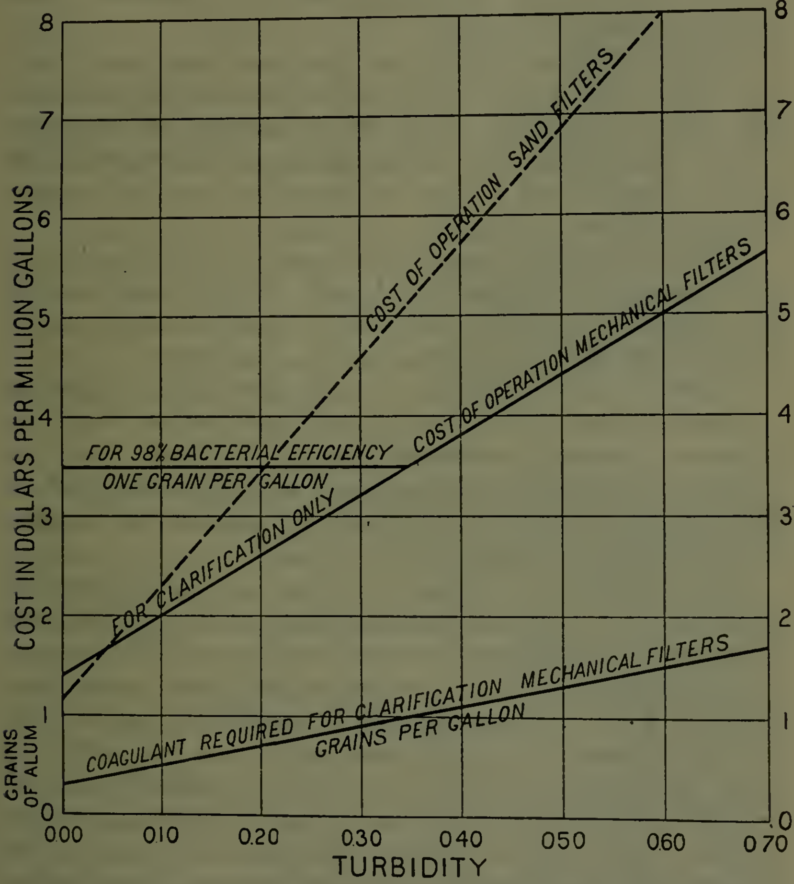
These three agencies constitute the clarifying power in sand filtration without coagulant. In mechanical filtration the rate of filtration is greatly increased, and all of them, and especially the last two, are very much limited in their action. The velocity of flow is so great as not to allow of either sedimentation or adhesion, or at least not in anything like the degree in which they operate in sand filtration. On the other hand, a new agency is introduced, which is the fourth on our list, namely, coagulation.

The most common and successful coagulant is sulphate of alumina. Waters to be treated with it generally contain lime in solution as calcium carbonate. This reacts with the sulphate of alumina, forming calcium sulphate, which remains in solution, and aluminum hydrate, which forms a flocculent precipitate which surrounds and gathers together the finest particles in the water and forms them into aggregates which are removed by straining much more readily than the separate particles can be removed. The characteristic feature of filtration with coagulants consists in gathering the particles into aggregates and removing them as such.

One of the essential conditions of success in the use of coagulant is that the raw water shall contain more than enough lime to decompose the sulphate of alumina applied. The flood-flows require much larger quantities of coagulant for their clarification than do the waters at other times, and they usually contain much less lime than the normal flows. The reason for this is obviously that the water of the flood-flows is mostly composed of rain water which has come over the surface and without coming into very intimate contact with the soil, and consequently without having taken from it much lime, while the low-water flows contain a considerable proportion of water which has percolated through the soil and thus become charged with lime. It thus becomes an important question whether the flood-flows of a given stream carry enough lime to decompose the sulphate of alumina necessary for their clarification, and it may happen that serious difficulties will be encountered at these times, even with waters which ordinarily present no difficulty in this respect.

Regarding these two systems of filtration, it can be said that, within certain limits, each is capable of removing mud satisfactorily. In filtration without coagulant the rate of filtration must not be too great, especially with very turbid waters. It is more difficult oftentimes to remove the finest clay particles than to remove the bacteria: and to secure clarification, rates of filtration must be employed lower than would be necessary for bacterial purification.

I recently made some estimates of cost of clarifying waters of various degrees of turbidity by sand and mechanical filters. These estimates were made for a special set of conditions, and I do not know that they will fit others, but



Cost of operating sand and mechanical filters with waters of different degrees of humidity. Turbidity of water applied to filter is taken without reference to reduction by preliminary processes. Interest and depreciation charges are not included.

they have at least a suggestive value. The results shown by the diagram include only the cost of operation, and not interest and depreciation charges.

With sand filters the frequency of scraping is nearly proportional to the turbidity, and as scraping represents most of the expenses, the costs of operation are proportional to the turbidity, except the general costs, and the cost of the amount of scraping which is necessary with even the clearest waters.

With mechanical filters the amount of sulphate of alumina required for clarification increases with the turbidity, and most of the costs of operation increase in the same ratio. The diagram shows the amount of sulphate of alumina in grains per gallon necessary for clarification with different degrees of turbidity.

With the clearest waters the costs of operation on the two systems are substantially equal. With muddy waters, the expense of operating sand filters increases more rapidly than the expense of operating mechanical filters.

There is another element which often comes into the comparison, namely, the question of purification from the effects of sewage pollution. Nearly all rivers used for public water supplies receive more or less sewage, and in filtering such waters it is regarded as necessary to remove as completely as possible the bacteria.

The quantities of sulphate of alumina required for the clarification of the least turbid waters are not sufficient to give even tolerably good bacterial efficiencies. To secure a reasonably complete removal of bacteria with mechanical filters, the use of a considerable quantity of sulphate of alumina is required. Let us assume that 98 per cent. bacterial efficiency is required, and that to produce this efficiency it is necessary to use one grain of coagulant to the gallon. With water requiring less than this quantity of coagulant for clarification, this quantity must nevertheless be used, and the costs will no longer decrease with decreasing turbidity.

I have added this line to the diagram, and this, combined with the upper portion of the line showing cost of clarification, represents the cost of treating waters with mechanical filters, where both bacterial efficiency and clarification are required.

This line, considered as a whole, increases much less rapidly with increasing turbidity than does the corresponding line for sand filters, and the two lines cross each other. With the clearest waters sand filters are cheaper than mechanical filters, and for the muddiest waters they are more expensive. It does not appear from the diagram, but it is also true in each case, that the cheaper system is also the more efficient. Sand filters are more efficient in removing bacteria from clear waters than are mechanical filters, and mechanical filters are more efficient in clarifying very muddy waters than are sand filters.

I have been able only to outline some of the problems presented in the clarification of muddy waters. The solution of them, and of the still more difficult problems which arise in the case of larger rivers than those considered this evening, will result in freeing American cities from the discomforts of muddy waters.

DISCUSSION.

PROF. F. LYNWOOD GARRISON:—The statements made by Mr. Hazen and other competent authorities, as to the relative bacterial efficiency of mechanical as compared with sand filtration, are rather surprising in view of the vastly greater speed of the former over the latter. There would seem, however, no good reason for doubting these conclusions, as they appear to have been well established by repeated careful and elaborate experiments. From the data thus obtained it is evident the practical efficiency of the mechanical filtering devices is simply a question of allowing proper time for settling and the use of a sufficient quantity of sulphate of alumina (alum). In the use of this chemical compound lies the essential difference between the two systems, and it is a question whether the cure is not worse than the disease, since the objectionable bacteria are replaced by the probably equally deleterious alum.

It has been well established that certain disorders may be directly traced to the continuous consumption of drinking water purified with the use of alum. Briefly, they may be said to consist of a general impaired digestion, irritation of the mucous membrane of the digestive tract, and if gastric troubles already exist, very serious consequences may follow the habitual use of water possessing astringent properties. As is well known such water is also quite objectionable for some industrial purposes, and in the bath and laundry.

The neutralization of the alum present in water can, of course, be effected by the use of lime or other alkalies, but the operation is at best a delicate one when performed upon a necessarily large scale, since the chemical composition of the water is probably seldom if ever constant, and the amount of alum used must vary from day to day in accordance with the quantity of matter held in suspension and the variable number of bacteria present as indicated by the biological test. There are, therefore, grave objections to the treatment by such complicated methods of the water-supply of our large cities. The simplest filtration method, even if the slowest and most costly at the beginning, will doubtless in the end prove the more effective and cheapest. The problems here presented are of the greatest and most vital importance to the city of Philadelphia, whose water-supply at present is undoubtedly contaminated by sewage and rendered disagreeable to the senses by the large and miscellaneous variety of suspended matter contained therein.

MR. P. A. MAIGNEN:—I should like to ask Mr. Hazen if, in the figures he gives us as representing the cost of operating mechanical filters, he has included the cost of the filtered water needed for washing the sand.

This represents a considerable item which should not be lost sight of. For instance, according to Mr. Fuller's report on the Louisville experiments, it is estimated that additional filters should be provided in times of average turbidity equal to 30 per cent., and at times of flood equal to 75 per cent. of actual requirement in order to clarify the water needed for washing the sand.

In other words, if the quantity to be filtered at the Queen Lane Reservoir be 70,000,000 gallons daily; in times of flood it would be necessary to pump 52,500,000 gallons of water in excess. This water would have to receive the usual quantity of coagulant, and it would have to be filtered before it is used for washing the sand.

The cost of pumping these additional 52,500,000 gallons would be \$2.12 by $\frac{238}{100}$ feet = \$5.04 per 1,000,000 gallons.

The cost of alum, which at this particular time would be required, would amount to \$7 per 1,000,000 gallons.

The cost of clarifying this water after coagulation would be, according to Mr. Hazen's computation, about \$3.50 per 1,000,000 gallons.

The water needed to cleanse the sand that has filtered 70,000,000 gallons would, therefore, cost \$5.04 plus \$7 plus \$3.50 = \$15.54 per 1,000,000 gallons, multiplied by $\frac{52,500,000}{70,000,000}$ = \$11.65 per 1,000,000 gallons, in addition to the cost of filtering the water for city use.

Mr. Hazen admitted that this cost was not included in the cost of operation of mechanical filters as shown in his diagram.

Special Meeting, January 3, 1899.

METHODS FOR THE EXAMINATION OF EXPLOSIVES.

By W. J. Williams, F.I.C., F.C.S.,
Member of the Institute.

In this paper I intend to give a brief outline of the methods used for the examination of smokeless powders, as laid down by the regulations of the War Department and practiced at Frankford Arsenal.

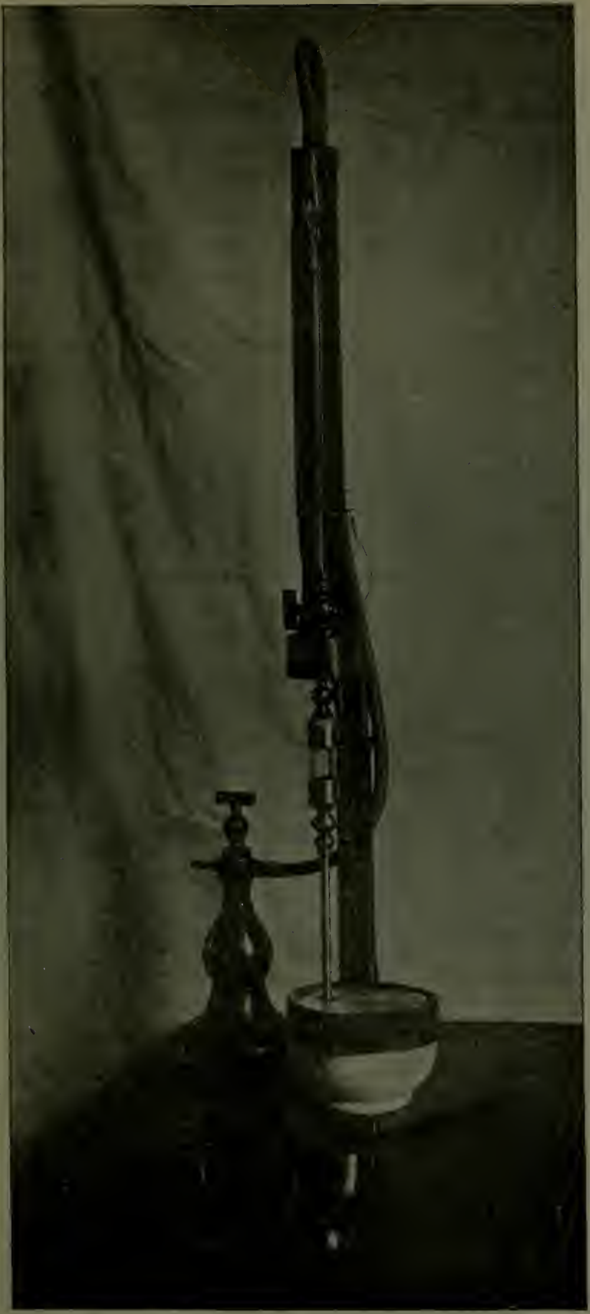
In general, the ingredients of smokeless powders used in the service are nitro-glycerine, gun-cotton or nitro-cellulose and sometimes a salt of picric acid, usually ammonium picrate. To these are added small quantities of inert materials, such as oil or paraffin, resin, urea, camphor, etc., for the prevention of decomposition and for modifying the rate of combustion.

In the first place we will consider the "service tests" of a smokeless powder.

The first point taken into consideration is the "stability" of the powder, *i. e.*, its liability to decomposition under the influence of heat. This is measured by the length of time that the powder will stand a temperature of 150° F. before the nitro compounds suffer decomposition; and is carried out in this way. Potassium iodide is re-crystallized from alcohol, and 1 gram is dissolved in 250 cubic centimeters H_2O. Three grams starch, previously well washed in distilled H_2O, are added to 250 cubic centimeters water, slowly heated to boiling, and boiled gently for fifteen minutes. The two solutions are then mixed. Strips of well washed filter paper are dipped in the mixture for ten seconds, and are then hung up to dry in a warm, dark place, free from laboratory fumes. These strips are then cut into suitable lengths, about 25 millimeters by 10 millimeters for the test.

When used they are moistened on the upper half with a drop of a 20 per cent. solution of glycerine in water.

The test is made in a cylindrical water bath, heated by an outer hot water bath to a temperature of 150° F. or 65° C. The bath in which the test is made has an aperture of about 5 inches diameter. It is covered with a loose sheet of copper, pierced with four or five holes just large enough to receive the test tubes, which are held in place by converging slips of brass wire, which act as springs. The material to be tested is then placed in the test tube, occupying a depth of about ½ inch; a piece of filter paper is affixed to a platinum hook on the end of a glass rod (which passes through the rubber cork closing the test tube) and moistened with a drop of glycerine solution, and the tube passed through an orifice in the lid of the bath (which has been previously heated to 150° F. or 65° C.) to such a depth that the powder is just immersed. Soon after the tube has been introduced a ring of moisture forms a little way up the tube, and then the position of the test paper is fixed by adjusting it so that the line of demarcation of the wet and dry portion of test paper coincides with the lower edge of



Du Pont densimeter.

the ring of moisture. When, under the action of heat, the nitrogen oxides or acids are set free, they decompose the KI and a faint yellow or brown line is formed on the paper. If this coloration is produced in less than fifteen minutes, the powder is considered unstable. The temperature of 170° F. or 77° C. for gun-cotton, and of 180° F. or 82° C. for cordite and other explosives, is prescribed by the English home office.

The next proceeding is to determine the specific gravity. The absolute specific gravity of a powder is determined by means of mercury in a vacuum. A cylindrical glass vessel or vase is mounted in metal fittings, so that it can be screwed in place at the foot of a shortened barometer tube. To the lower end of this is screwed a hollow metal tube, so as to bring the whole apparatus to its proper height with the graduations marked on the upper portion of the barometer tube. The lower end of this hollow metal tube dips in a reservoir of mercury. First the vase is screwed into place, the tube adjusted, and then by means of an air pump a vacuum is produced until the mercury rises to the height of the barometer, thus completely filling the vase. The temperature of the mercury is accurately noted and the vase is detached and accurately weighed. It is now emptied of mercury, a known weight of powder introduced, and again replaced in position. A vacuum is produced as before, and the mercury again raised to the barometric height, thus filling all the unoccupied space in the vase. The vase is unscrewed and reweighed, again noting temperature of mercury. The difference between this weight and the previous one gives the weight of mercury at the noted temperature which occupies the same space as the known weight of powder. Now we have all the data for calculating the absolute density of the powder.

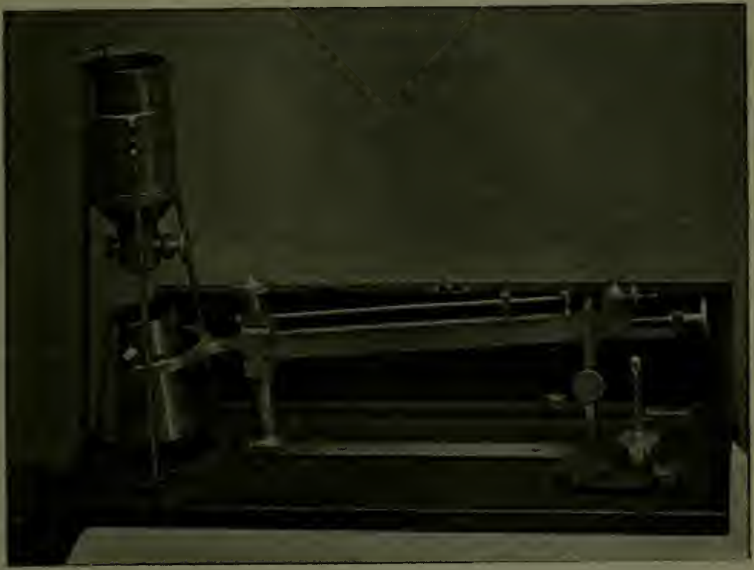
If D = density of powder sought,
P = weight of vase filled with mercury,
P' = weight of vase filled with mercury and powder,
d = density of mercury at $Tx°$,
a = weight of powder taken,

then $$D = \frac{d \times a}{P - (P' - a)}$$

P′ — a = weight of vase, Hg and powder
— weight of powder taken
P — (P′ — a) = weight of Hg displaced by powder.

The next thing to be determined is the gravimetric density. This is not easy to define. A rough definition is "the weight of the grains of powder including the air in the interstitial spaces contained in unit volume." Perhaps a better definition would be:

"The ratio which the weight of the substance bears to the volume it occupies."



Du Pont gravimetric balance.

It is obvious that the gravimetric density of a powder is quite distinct from, and independent of, its specific gravity. In fact, a very dense powder may give a much lower gravimetric density than a powder of low specific gravity. Gravimetric density is usually expressed by the weight of a cubic foot in ounces.

The instrument used to determine the gravimetric density is known as the Du Pont gravimetric balance. It consists of a small beam scale resting on a steel knife edge, one end of which terminates in a semi-circular jaw, which supports a vase hanging on trunnions. The other arm of the beam is graduated into 100 equal parts, marked from 800–900, which are read as ounces. Below the 900 mark is a small hook, to which weights marked 100 and 200 ounces can be attached when necessary.

To ascertain the gravimetric density, the vase is placed in position on the knife edges of the jaw, the counterpoise is placed in it, the 100-ounce weight hooked on and the rider set at 800, and then the beam is put into equilibrium by adjusting the sliding weights. Now remove the vase, fill it lightly with powder from the hopper, without any jarring or shaking, till it overflows and then "strike" it with a straight edge. Replace the vase on the jaw and again produce equilibrium by the weights and rider. The figures give the gravimetric density without calculation, as the graduations are so arranged that the vase filled with distilled water would show 1,000 on the scale.

Powders are then submitted to various exposures. A known weight, on a fine sieve, is placed in an air bath heated to 130° F. for twenty-four hours. The loss of weight noted. Another portion, also on a fine sieve, is exposed on a tray in a box, with tight-fitting cover, over water, so that it remains in an atmosphere saturated with moisture for twenty-four hours; and the increase of weight noted, also the temperatures prevailing during the test in the hygroscope.

A second weighed portion is exposed in the same way to moisture for twenty-four hours, the temperatures being noted also, weighed to ascertain the moisture absorbed and then exposed on a glass plate to a free current of air, protected from any loss by draughts, for a further twenty-four hours, and the weight again noted. This shows the powder's power to throw off the moisture previously absorbed in the hygroscope, by simple exposure to air. The variation in the temperature and the humidity of the atmosphere is carefully noted during the exposure. Another weighed portion is exposed, similarly, directly to air and the gain or loss of weight noted. The temperature and humidity are also observed.

A weighed portion of powder is exposed in an air-tight box to extreme cold from —35° F. to —40° F. for six hours, and the gain or loss in weight noted. It is then exposed to the air for twenty-four hours, and the gain or loss of weight noted.

The powder, as received from the manufacturer, is, of course, tested in the proof house for the velocity it imparts to the projectile and for the pressure exerted in the gun. After each of the above-mentioned exposures to heat, moisture, moisture and air, air, and cold and air, respectively, the velocity and pressure produced are tested, so that the practical effects of each exposure on the powder, or the variation in its practical effectiveness caused by each exposure, is ascertained. Cartridges are loaded with the powder and are exposed to heat at 130° F. for twenty-four hours, to moisture in the hygroscope for one week, and to cold of —35° to —40° F. for six hours, in precisely the same way, then fired to ascertain the variation in the velocity and pressure produced in the made-up cartridges by these exposures.

The condition of granulation of the powder causes great variation in the rate of combustion, and consequently in the velocity of the projectile and the pressure on the gun. It is, therefore, very necessary that the granulation of each shipment should vary as little as possible from that of previous shipments, or that the granulation should be uniform. The powder is sieved through a set of sieves having circular perforations ranging from ·10 inch to ·09, ·08, ·07, ·06, and ·03 inch, and the proportion resting on each sieve weighed.

Lastly a weighed portion of the powder is fired on a watch glass and the residuum of ash weighed. This represents roughly the "fouling" capacity of the powder.

This series of tests constitute what are known as the "Service tests" of the powder.

CHEMICAL TESTS.

The power or effectiveness of an explosive may be approximately measured by its content of nitrogen. Thus:

			Per cent.
Cellulose	$C_{12}H_{14}O_4\ (O.H)_6$		
Hexa-nitro-cellulose	$C_{12}H_{14}O_4\ (O.No_2)_6$	contains	14·14
Penta-nitro- "	$C_{12}H_{15}O_5\ (O.NO_2)_5$	"	12·75
Tetra-nitro- "	$C_{12}H_{16}O_6\ (O.NO_2)_4$	"	11·11
Nitro-glycerine	$C_3H_5\ (O.NO_2)_3$	"	18·50
Picric acid	$C_6H_2O.H.\ (NO_2)_3$	"	18·34
Potassium nitrate	$K.NO_3$	"	13·86
Sodium nitrate	$NaNO_3$	"	16·47

The readiest means of estimating nitrogen in a nitrate or nitric ester is by Crum's method, viz.: By dissolving the substance in concentrated sulphuric acid and then violently agitating with metallic mercury. The nitric acid is decomposed with formation of nitric oxide, NO, and mercury sulphate. The volume of nitric oxide gas liberated is corrected for temperature and barometric pressure according to the formula

$$V^{1} = \frac{V \mathrm{\ x\ } B}{760 \mathrm{\ x\ } (1 + \delta t)}$$

and as 1 cubic centimeter of NO gas = 0·6267 milligram N the content of N can be readily calculated from the NO gas found. Lunge's Gas Volumeter, in which the gas evolved is transferred to another burette for reading and which is provided with a "reduction" tube or air vessel, whereby the gas evolved can be at once compressed to its true volume, saves much calculation. It has a further advantage over the ordinary form of nitrometer in that the gas is separated from the acid, so that no correction need be made for this column of acid. A smokeless powder is of a tough, horny character, very difficult to grind, and unless in a very fine state of division, very slow to dissolve in concentrated H_2SO_4. I find a good way of handling it is to file or rasp off a sufficiency of the powder, sieve through a 60-mesh sieve and take the fine portion for nitrogen estimation. It is desirable to use as little H_2SO_4 as possible for solution, for two reasons; one is that NO gas is appreciably soluble in H_2SO_4, the solubility is 0·21 cubic centimeter NO gas in 15 cubic centimeters H_2SO_4; and the other is that if a large amount of H_2SO_4 is used the quantity of NO gas evolved is always a little too low. This is probably due to an incomplete decomposition of the nitric acid from the difficulty of obtaining perfect contact with the mercury when the quantity of acid is too large. About 300 milligrams of powder is a very convenient quantity to operate upon. This is placed in the cup of the nitrometer and 4 or 5 cubic centimeters of concentrated H_2SO_4 poured upon it. It is stirred and rubbed against the sides of the cup with a platinum or glass rod at intervals and the cup closed with a cork. Generally a smokeless powder takes about four hours to completely dissolve, very seldom less time. The textbooks say that the solution is ready for decomposition *as soon as it will flow* but my experience is that unless solution is *perfect* the results will be too low. Even a finely divided gun-cotton requires about two hours for perfect solution. Apparently it is all dissolved in about thirty minutes, but a close scrutiny will show that it is in a translucent gelatinous form; and I find it seldom fully dissolves under two hours. The solution is run into the nitrometer, the cup carefully rinsed with dilute H_2SO_4 (1 volume concentrated H_2SO_4 to 1 volume H_2O), of which it is desirable to use as little as possible. By rinsing with about 1 cubic centimeter at a time in a pipette, I find that 4 to 5 cubic centimeters are sufficient for perfect rinsing. The use of dilute H_2SO_4 for rinsing always gives results about 0·2 per cent. higher than if concentrated H_2SO_4 is used. This I believe is due to the rise in temperature giving a more perfect reaction with the mercury. It has been suggested that the high result is due to the aqueous vapor introduced, but I do not consider this probable as there is present at least 6 cubic centimeters concentrated H_2SO_4 to 2 cubic centimeters H_2O (or about 10·8 grams acid to 2 grams H_2O) and that seems amply sufficient acid to retain all H_2O. When the rinsing is completed the nitrometer is shaken violently till the reaction is over. It is advisable to repeat this shaking once or twice. The instrument is left at rest twenty to thirty minutes to equalize temperature with the surrounding atmosphere. Then the gas is transferred to the measuring burette, the volume corrected for temperature and pressure and the N calculated from the volume of gas found. It is important that the mercury in the measuring burette should be perfectly dry as any aqueous vapor makes a very appreciable difference in the volume of gas.

The gas volumeter as designed by Lunge is a far preferable instrument to the ordinary nitrometer. When the "reduction" tube has been once filled with the quantity of air at the temperature and barometric pressure of the laboratory equal to 100 cubic centimeters at normal temperature and pressure, this remains good (with ordinarily good taps well greased and carefully closed) for at least two weeks, thereby saving much unnecessary calculation; of course, if the gas volumeter has not been used for a few days, it is always well to take a double reading—one at the current temperature and pressure and again when the air in the reduction tube is compressed to normal temperature and pressure. The first reading, when corrected, should equal the second reading, if no leakage has occurred.

It is always desirable to take the N determination by this method on a perfectly dry sample of powder. The method is only applicable to nitrates and nitric esters, which give up NO on agitation with mercury. It is, of course, inapplicable to nitro-substitution compounds such as picrates, nitro-naphthaline, etc., in which case I find a modified Kjeldahl or Gunning method the readiest and most accurate process for N determination.

About 0·5 gram of the finely-ground sample is placed in a long-necked Kjeldahl digestion flask, and 30 cubic centimeters of concentrated H_2SO_4 (in which 2 grams of salicylic acid quite free from N. has been dissolved) are poured over it, and it is set aside till completely dissolved. This frequently requires many hours. When solution is complete add gradually 5 grams crystallized sodium thiosulphate. Then heat gently till the violent reaction and frothing has subsided. Add a drop of metallic mercury and boil briskly till the liquid is colorless or of a pale amber yellow. This frequently requires four to six hours with a tough horny powder. Finally, complete oxidation with a little potassium permanganate. The oxidation can be much accelerated by adding 5 to 10 grams powdered potassium sulphate about fifteen minutes after boiling has commenced, as proposed by Gunning. When oxidation is complete, the flask is cooled and its contents transferred to a distilling flask with about 200 cubic centimeters water, and a little zinc or platinum to prevent bumping. Add a little potassium sulphide solution to decompose mercury compounds and then sufficient sodium hydrate to render the contents of the flask alkaline; distil over into semi-normal acid and titrate with decinormal ammonia. This is a very accurate method and very useful as a check on the nitrometer determinations.

It may be interesting to show the close agreement in determinations by the nitrometer and by the Kjeldahl method:

	N. by Nitrometer. Per Cent.		By Kjeldahl. Per Cent.	Diff.
Sm. powder	13·632		13·654	0·020
“ “	14·305		14·246	0·059
“ “	13·475		13·462	0·013
“ “	13·936		13·986	0·050
German Sm. powder	13·509		13·465	0·034
“ “ ballistite	12·836		12·823	0·013
Gun-cotton	12·662		12·660	0·002
“	13·152		13·096	0·056
Picric acid theory	18·340	found	18·337	0·003
Sm. powder, Nas nitric ester	12·449			
Calculated from percentage of picrate	4·865			
Total N	17·314	“	17·435	
Sm. powder, Nas nitric ester	11·509			
Calculated from percentage of picrate	4·552			
	———	“	16·046	
Total N	16·061	“	16·122	

MOISTURE AND VOLATILE MATTER.

Most powders, and gun-cottons in the colloidal condition, have been dissolved in acetone, amyl acetate or other solvent in the course of manufacture; and although the bulk of this solvent is removed, the powder still retains 1 or 2 per cent. The fine sample is exposed to a temperature of 50° C. (120° F.) in an air bath for twenty-four hours. The air bath is fitted with a thermostat, so that a constant temperature is maintained. After twenty-four hours' exposure to 50° C., the sample is placed in a desiccator over concentrated H_2SO_4 or $CaCl_2$, and a good vacuum produced by a Sprengel or other air pump. As a rule, twenty-four hours in a vacuum is sufficient, though sometimes a particularly horny and tough sample will require even longer.

For safety in transit, nitro-glycerine is frequently mixed with acetone, which has to be removed before estimating the nitrogen. This is done by adding water to the mixture, which dissolves the acetone and the mixture is transferred to a separating funnel, and the heavy nitro-glycerine soon settles and can be run off through the tap. The washing with water is repeated two or three times, and it is well to let the last washing stand over night to allow the water ample time to separate. A funnel is prepared by plugging the stem with asbestos and half filling it with dry salt, NaCl; the nitro-glycerine is filtered through this NaCl, which removes the last traces of moisture. It is then ready for the determination of N in the gas volumeter.

ANALYSIS OF EXPLOSIVES.

In the first place we will consider a simple explosive, *e. g.*, gun-cotton.

The determinations are moisture, "soluble cotton," pyroxylin or collodion, which is a mixture of penta- and tetra-nitro-cellulose, gun-cotton or hexa-nitro-cellulose, unnitrated cotton or cellulose, and ash, and, of course, total nitrogen.

The moisture and nitrogen we have already considered. A very excellent, but slow, method of determining the pyroxylin is to extract a weighed portion of the cotton with methyl alcohol in a Soxhlet's extractor. This is accurate, but very slow, as the cotton gelatinizes and chokes the linen filter. The *modus operandi* is as follows: A thistle tube has its stem plugged loosely with glass-wool, a perforated platinum disc overlays this plug and this is covered by a linen filter. The weighed portion of gun-cotton is introduced. The tube placed in the Soxhlet extractor and the lower bulb filled with methyl alcohol and heated in a hot water bath. The extraction takes five or six days; of course it requires but little attention, and practically runs itself. All that is required is to replace the evaporated water in the bath and to see that the temperature does not get too high. When extraction is complete the thistle tube and its contents are dried at 50° C. and reweighed the loss = pyroxylin.

The gun-cotton is extracted from the residue in precisely the same way, but acetone or acetic ether is the solvent used, and the loss of weight = gun-cotton. The residue is unnitrated cotton or cellulose.

An equally accurate and much quicker method of estimating pyroxylin is to weigh out, say 3 grams of the sample and transfer to a graduated cylinder of a capacity of 150 cubic centimeters. Now add 50 cubic centimeters absolute alcohol and allow the cotton to soak and disintegrate for say thirty minutes, then add 100 cubic centimeters pure ether and shake at intervals for twelve hours or more. Allow to settle, withdraw 50 cubic centimeters of the solution and evaporate to dryness in a platinum basin, the residue is pyroxylin. This can be checked by withdrawing a second portion of 50 cubic centimeters and precipitating the pyroxylin with chloroform and filtering through a weighed linen filter. It is advisable to redissolve this precipitate in a mixture of 1 part alcohol and 2 parts ether, and reprecipitate with chloroform, dry the precipitate at 50° C. and weigh. This second precipitation is obligatory in a powder which also contained nitro-glycerine, otherwise nitro-glycerine is retained in the gelatinous pyroxylin.

Cellulose or unnitrated cotton is estimated in this way: A weighed portion, about 5 grams, of the sample is treated with 30 cubic centimeters of a saturated solution of sodium sulphide, or sodium stannite, and boiled for thirty minutes and allowed to stand twenty-four hours, settled and the solution decanted. It is then boiled with a second portion of 30 cubic centimeters saturated sodium sulphide solution and then filtered on a weighed filter and washed with H_2O. Then washed three or four times with a 5 per cent. solution of hydrochloric acid to remove any metallic salts, washed free from acid with water, dried and weighed. The filter is then incinerated, the ash weighed and deducted from the previous weight. The remainder equals cellulose.

The ash of a gun-cotton is determined by mixing a weighed portion in a platinum crucible with melted paraffin, cautiously heating until the paraffin inflames, and allowing it to burn away slowly, finally raising the heat till only the ash remains unconsumed.

ANALYSIS OF A POWDER.

The analysis of a powder containing nitro-glycerine, a picrate and gun-cotton with paraffin or oil, resin, camphor, sulphur, urea, metallic salts, etc., is a very complicated and tedious procedure.

The finely divided and dried sample is first treated with ether, either in a Soxhlet extractor or in a flask, and poured through a linen filter. The ether dissolves out the nitro-glycerine, paraffin or oil, camphor, resin and part of the sulphur, and part, if not all, of the picrate. The loss of weight represents total ether extract.

If picrates are present the ether extract is mixed with water in a separator, the picrates pass into the water solution, which is then separated from the ether solution.

The ether extract is cautiously evaporated, best let it evaporate spontaneously, as it is almost impossible to prevent loss of nitro-glycerine if the temperature be raised.

The dried extract is treated with carbon disulphide, the CS_2 is decanted into a weighed beaker, this is repeated three or four times, then the CS_2 is cautiously evaporated and the camphor volatilizes along with the CS_2. Now let A represent the weight of the total ether extract. Let B represent the residue of A after extraction with CS_2, and let C represent the residue left of the CS_2 extract after the CS_2 and camphor have evaporated, then $A - (B + C) =$ weight of camphor extracted by CS_2 and volatilized with it.

Having determined the camphor, the two residues are mixed together and digested with sodium hydrate on a water bath, mixed with ether and separated.

The ether solution contains the oil and paraffin, which is weighed after evaporating the ether.

The water solution is oxidized with bromine, HCl is added, which precipitates the resin, which is filtered and weighed on a filter of known weight. The sulphur which has been oxidized by bromine is precipitated as $BaSO_4$ and ignited and weighed.

After treatment with ether the powder is next extracted with hot water. This dissolves any picrates, urea and metallic nitrates and chlorates and water-soluble salts. The picric acid is precipitated by cinchonine sulphate, and the metallic salts are determined by the usual well-known methods.

There now remains the pyroxylin, true gun-cotton, cellulose and ash, which are determined as previously described in the analysis of gun-cotton.

Instead of extracting with ether alone, the first extraction may be made with a mixture of 1 part alcohol to 2 parts ether. This extracts pyroxylin in addition to all the substances dissolved by ether, and the pyroxylin is precipitated by chloroform and filtered. This gelatinous precipitate should be redissolved in ether-alcohol and reprecipitated to remove all the nitro-glycerine.

If metallic salts are present besides nitrates, chlorates and other water-soluble salts, and they usually are, as sodium carbonate, or carbonates of the alkaline earths are generally used to finally neutralize the gun-cotton, they are extracted from the residue left after treatment with sodium sulphide. This residue consists of cellulose and these metallic salts insoluble in water. This residue is treated with hydrochloric acid and the metallic salts determined in the usual way.

Powders are frequently graphited; this gives them a glossy black appearance, and is said to prevent the absorption of moisture.

APPENDIX.

THEORY OF GUN-COTTON.—*Formation from Cellulose.*

$$C_{12}H_{14}O_4(O.H)_6 + 6HNO_3 = C_{12}H_4O_4(O.NO_2)_6 + 6H_2O$$

According to the theory of Eder he produced

Per Cent.

$C_{12}H_{14}O_4(O.NO_2)_6$ Hexa-nitro-cellulose, containing 14·14N $\left\{ \begin{array}{l} \text{insoluble in} \\ \text{ether and alcohol.} \end{array} \right.$

				Per Cent.	
$C_{12}H_{15}O_5(O.NO_2)_5$ Penta-	"	"	"	12·75N	soluble in ether and alcohol.
$C_{12}H_{16}O_6(O.NO_2)_4$ Tetra-	"	"	"	11·11N	soluble in ether and alcohol.
$C_{12}H_{17}O_7(O.NO_2)_3$ Tri-	"	"	"	9·15N	soluble in ether and alcohol.
$C_{12}H_{18}O_8(O.NO_2)_2$ Di-	"	"	"	6·76N	soluble in ether and alcohol.

but he did not succeed in producing mono-nitro-cellulose.

Vicille made gun-cotton, with an excess of acid, at a temperature of 11° C., and found eight stages of nitro-cellulose, therefore, he assumed the formula of cellulose must be doubled, and assigned these formulæ to the different stages.

				Per Cent.	
$C_{24}H_{28}O_8(OH)_{12}$ Cellulose.					
$C_{24}H_{18}O_9(NO_3H)_{11}$ Endeca-nitro-cellulose, cont'g				13·47N	insoluble in ether and alcohol.
$C_{24}H_{20}O_{10}(NO_3H)_{10}$ Deca-	"	"	"	12·75N	insoluble in ether and alcohol.
$C_{24}H_{22}O_{11}(NO_3H)_9$ Ennea	"	"	"	11·96N	soluble in ether and alcohol.
$C_{24}H_{24}O_{12}(NO_3H)_8$ Octo-	"	"	"	11·11N	soluble in ether and alcohol.
$C_{24}H_{26}O_{13}(NO_3H)_7$ Hepta-	"	"	"	10·18N	gelatinous in ether and alcohol.
$C_{24}H_{28}O_{14}(NO_3H)_6$ Hexa-	"	"	"	9·15N	slightly attacked by ether and alcohol.
$C_{24}H_{30}O_{15}NO_3H)_5$ Penta-	"	"	"	8·02N	slightly attacked by ether and alcohol.
$C_{24}H_{32}O_{16}(NO_3H)_4$ Tetra-	"	"	"	6·76N	slightly attacked by ether and alcohol.

These formulæ are not generally accepted. Gutmann has made gun-cotton with 13·65 per cent. N on a very large scale, which would be impossible, according to Vicille's theory.

Gun-cotton is a nitric ester or nitric ether. Concentrated sulphuric acid decomposes it, liberating nitric acid. Concentrated potassium hydroxide and sodium hydroxide form the corresponding nitrates with slow re-formation of cellulose at ordinary temperatures; this action is quickened at a temperature of 60° to 80° C.

At high density of charge (about 0·20) gun-cotton decomposes thus :

$$2(C_{24}H_{29}(O.NO_2)_{11}) = 24CO_2 + 24CO + 12H_2O + 17H_2 + 11N_2$$

$$46{\cdot}19 + 29{\cdot}40 + 9{\cdot}45 + 1{\cdot}49 + 13{\cdot}47 \text{ per cent.}$$

and 1,143 grams yield 1,168 calories, water considered gaseous.
or 1,227 " " " liquid.
or 1 kilogram yields 1,022 " " " gaseous.
or 1,074 " " " liquid.
and 859 liters of gas, at constant pressure

At low density of charge (about 0·023) its decomposition is

$$2(C_{24}H_{29}(O.NO_2)_{11}) = 18CO_2 + 30CO + 18H_2O + 11H_2 + 11N_2$$

$$34{\cdot}65 + 36{\cdot}75 + 14{\cdot}17 + 0{\cdot}96 + 13{\cdot}47 \text{ per cent.}$$

and 1,143 grams yield 1,140 calories, water considered gaseous.
or 1,230 " " " liquid.
or 1 kilogram yields 998 " " " gaseous.
and 1,076 " " " liquid.
and 859 liters of gas at constant pressure.

It will be observed that neither NO nor other nitrous oxide gases are produced by explosive decomposition in closed vessels. When the gases are allowed to escape freely under a pressure about equal to that of the atmosphere, then NO is formed. But the products of decomposition vary according to the conditions of density of charge, pressure exerted, and so on very greatly, especially if the gases are allowed to cool, but remain fairly constant at constant pressure.

Nitro-glycerine is a nitric ester or nitric ether of glycerine. Its formation is according to the equation

$$C_3H_5(OH)_3 + 3HNO_3 = C_3H_3(O.NO_2)_3 + 3H_2O$$

Potassium and sodium hydroxides decompose it, forming the corresponding nitrates and glycerine. If it were not a nitrate, but a nitro compound, it would produce amido compounds when reduced by nascent hydrogen, ammonium sulphide, etc , as nitro-benzene and picric acid do under similar conditions.

A di-nitro- and mono-nitro-glycerine can be conjectured, and it is probable they are formed and at once dissolved by the excess of H_2SO_4. They are also soluble in water. Liecke says that by using nitric acid of sp. gr. 1·3 he produced mono-nitro-glycerine, and by using acid of sp. gr. 1·4 he formed di-nitro-glycerine, and with acid of sp. gr. 1·5, he obtained tri-nitro-glycerine. These statements have not been verified.

Henriot claims he made mono-nitro-glycerine by mixing glycerine with dilute HNO_3 (1 part acid to 3 parts water). He says it is easily soluble in water and alcohol, difficultly soluble in ether, and does not explode by shock.

Nitro-glycerine in large quantities explodes at 180° C. (356° F.). Nitro-glycerine decomposes thus:

$$2(C_3H_5(O.NO_2)_3) = 6CO_2 + 5H_2O + 3N_2 + O$$

$$58{\cdot}20 + 19{\cdot}80 + 18{\cdot}50 + 3{\cdot}50 \text{ per cent.}$$

and 227 grams yield 331·5 calories, water considered gaseous.
or 356·5 " " " liquid.
or 1 kilogram yields 1,460 " " " gaseous.
or 1,570 " " " liquid.
and 713 liters gas at constant pressure.

It may be interesting here to compare the calories and volumes of gas evolved by black powders and their solid residues.

BLACK POWDERS

of the general composition, potassium nitrate 75 per cent., sulphur 10 per cent., charcoal 15 per cent. This composition will be approximately expressed by the formula $16KNO_3 + 21C + 7S$, and the explosive decomposition by

$$16KNO_3 + 21C + 7S = 13CO_2 + 3CO + 8N_2 + 5K_2CO_3 + K_2SO_4 + 2K_2S_3$$

$$\underbrace{27{\cdot}34 + 4{\cdot}11 + 10{\cdot}71}_{\text{Gases } 42{\cdot}16} + \underbrace{32{\cdot}88 + 8{\cdot}32 + 16{\cdot}64}_{\text{Solids } 57{\cdot}84 \text{ p.c.}} \text{ p.c.}$$

Gay-Lussac found that 1 liter = 900 grams of sporting powder evolved

238 liters CO_2
22·5 " CO
189 " N
449·5 " gas.

Bunsen and Schischkoff obtained from 1 gram of powder 0·3138 gram gases = 193·1 cubic centimeters @ 0° C., and 760 millimeters, and 0·6806 gram solids.

Linck obtained from 1 gram of powder 0·358 gram gases = 218·35 cubic centimeters @ 0° C., and 760 millimeters and 0·6415 gram solids.

These solids and gases had the composition :

Solids.	B. & S.	Linck.
K_2SO_4	62·10	45·08
K_2CO_3	18·58	23·96
K_2S	3·13 K_2S_2	14·94
$K_2S_2O_3$	4·80	5·83
$2(NH_4)3CO_2$	4·20	3·18
C	1·07	2·85
KNO-	5·47	1·87
KSCy	0·45	1·81
S	0·20	0·48
	100·00	100·00

Gases.	B. & S.	Linck.
CO_2	52·67	52·14
CO	3·88	4.33
N	41·12	34·68
H	1·21	1·63
H_2S	0·60	7·18
O	0·52	0·04
	100·00	100·00

Karolyi obtained from 1 gram powder 0·3078 gram gases = 206·91 cubic centimeters @ 0° C., and 760 millimeters, and 0·692 gram solids.

Noble and Abel, from 1 gram of different powders : Gases 44·84 per cent. to 41·09 per cent. = 278·3 cubic centimeters to 241·0 cubic centimeters ; solids, 56·82 per cent. to 58·91 per cent. ; calories, 721 to 764.

These results may be compared thus :

1 kilogram gun-cotton evolves 1,074 calories and 859 liters gas.
1 kilogram nitro-glycerine " 1,570 " " 713 " "
1 kilogram black powder " say 740 " " 260 " "

or gun-cotton evolves about three times as much gas as black powder and about one and one-half times as many calories ; and nitro-glycerine evolves about two and one-half times as much gas as black powder and about twice as many calories.

Therefore, the potential energy of gun-cotton may be roughly considered as about four and one-half times that of black powder and the potential energy of nitro-glycerine may be roughly estimated as about five times that of black powder.

Stated Meeting, October 18, 1898.

THE FIELD FOR CHEMICAL IMPROVEMENT IN THE MANUFACTURE OF SUGAR.

BY WILFRID SKAIFE.

I wish to lay before you, as far as the limits of this paper will admit, a general idea of the field which the sugar industry presents to the chemist and chemical engineer for original research. The paper is written from the practical sugar-makers' point of view, and deals with those problems which present themselves daily to us, and whose solution is of commercial as well as scientific importance. The pure chemistry of the various sugars is not touched upon, for, while the work to be done in this direction cannot be overestimated, the field is too extensive.

To those who are familiar with practical sugar chemistry, it may seem that this field, in the present state of our knowledge, has been pretty well worked out, for no other industry has had more able chemists devote themselves to its study. From the time of Dubrunfaut, to whose wonderfully original mind we owe so much, a great number of good men have produced much good work. Robert, Scheibler, Stammer, Peligot, Berthelot, Casamajor, Maumene, Soxhlet, Biot, Lippman, Wiley, Stohman, Wiechman, Prinzens-Gerlig, Claassen and many others have built up a great literature of sugar. Through them our knowledge of the chemistry of sugar has been developed, and many great improvements in the extraction thereof, from the sugar-producing plants of the world, have resulted; but to indicate how little real advancement has been made for a long time, it may be pointed out that the latest and best beet sugar-house that has been erected this year, is constructed to use the method of clarification of the juice, described by MM. Perier & Possoz in the *Comptes Rendus* of August, 1860, and modified later on by Jelinek, and that the latest refinery is using the same char-decoloration process, discovered by Derosne, in 1812, and rendered practical by Dumont in 1828. The two great steps in the chemical treatment of sugar liquors—their clarification and decoloration—have remained the same, practically speaking, for forty and seventy years, respectively. Both of these are laborious and expensive processes, and have been subject to steady attack by able men for a long time past, without being even shaken in their position. Other serious problems are still untouched or are the subject of controversy.

I wish now to say that I assume a general knowledge of the manufacturing and refining of sugar, on the part of the readers of this paper, and will, therefore, only indicate the various points at which the skill of the chemist may find a field for the search, without describing minutely the regular daily work.

It is an old German saying that " man haut den Zucker in die Rueben hinein," otherwise, that sugar is made in the fields. The function of the agricultural chemist, in relation to the sugar manufacturer, is one of primary importance, as the work of Maercker, Kuen and Vilmorin, and a host of others can testify. The use of manures, scientifically, and the study of the diseases of the plant have greatly influenced not only the sugar content of the juice of the sugar-beet, but also the nature of the impurities contained therein ; for instance, by the suppression, in a great measure, of the use of potash salts, and in some ways of nitrogen, and by the study notably of Dr. Kuehn, of Halle, of the nematoden, whose spread threatened to be as serious to the sugar-beet as the phylloxera to the vineyard. Perhaps to Vilmorin is due, more than to any other, the wonderful result of raising the sugar content of the beet from 8 per cent. to 22 per cent., a triumph of agricultural chemistry, and an indicator of what may be done in this direction in the sugar-cane fields, where to-day no progress of practical value has been realized. The reasons for this are many; perhaps the greatest being the nature of the countries where the sugar-cane grows, but also, the nature of the plant itself, in that it produces only flowers that are not fertilized in a natural way, the propagation instead being caused by the sprouting of the joints underground. In consequence of this, the crossing of various kinds is nearly impossible, and we go on using the same unimproved plant and relying on empirical knowledge for the selection of the kind. I should state that here is the first and greatest field for the chemist—the study of the improvement of the cane and its economical manuring. Perhaps when the cane-sugar industry shall have such an establishment as we may see connected with the great seedsmen in Europe, where 3,000 or 4,000 polarizations are made in a day to select mother-beets, we may hope for some improvement in the cane fields. Cane has been raised from seed in Java, Demerara and elsewhere, but no practical results have come forth as yet.

Passing from the fields to the sugar-house, we have no chemical problem confronting us in the case of the sugar-cane, for it is, in a well-organized plantation immediately ground up, but sugar-beets, on the contrary, are stored in silos for several months, and a loss of crystalline sugar results, equal often to 2 per cent. on the weight of the beets, or over 10 per cent. of the total sugar in the juice. This loss occurs chiefly in the warmer countries where beet-sugar is made, and is severely felt, for instance, in some parts of France. It will naturally be caused by the sprouting of the beets in the silos, but also occurs apart from this; and to check it until the factory can slice up the whole crop, is a problem worthy of any chemist's skill.

To follow the sugar-beet, first, as it goes through the process of manufacture, the first chemical treatment which it undergoes is the extraction of the juice by means of diffusion. Mathieu de Dombasle, some seventy years ago, started the idea, and Robert of Seelowitz, thirty years afterwards, put into practical shape the process now universally in use, which, as you are all aware, is an imperfect osmosis, in which the uncut cell walls serve as the membrane and the broken cells discharge their whole content into the surrounding liquor. As handled to-day, the diffusion battery is a very excellent apparatus; the content in the sugar of the refuse being only ¼ of 1 per cent. after an hour's contact with water, and the juice of a better quality is obtained more rapidly than in any other way. A great deal has been written concerning the handling of batteries, the question of temperature, etc., but still there remains one important matter from the manufacturers' point of view, and that is the dilution of the juice. Instead of obtaining juice of the same density as in the original beet, we have one containing 10 per cent. to 20 per cent. more water which has to be evaporated later on at the expense of so much fuel. This dilution may be reduced by either raising the temperature of the battery, or by increasing the time of contact, but the former results in the extraction of a more impure juice, and the latter necessitates a much increased capacity. It is possible that a partial solution of the problem, at least, lies in acting on the slices by water under high pressure. It may certainly be assumed that if the process of dialysis is to be relied upon, all we can do to hasten matters is to provide for a more intimate contact between the cell wall and the water, for we cannot change the character of the cell wall without damage to its value as a membrane, nor can we use any liquid except alcohol, which will cause the more rapid passage of the crystalline sugar, and needless to say, its use is not to be considered, on account of the expense.

The diffusion process, so successful in beet-sugar manufacture, has found little application as yet in cane-sugar houses, principally on account of the dearness of fuel in the countries where cane-sugar grows. The grinding of the cane in mills produces a juice without dilution, or of a dilution that can be easily controlled, and is a purely mechanical operation, leaving a residue (bagasse) containing 7 per cent. of sugar, which supplies all the fuel needed for the production of the steam. It seems a wasteful business to burn sugar, but the reduction of the sugar content of the bagasse by pouring water on the mills is of doubtful value, inasmuch as a great many impurities are carried into the liquor along with the sugar, and an increase in the quantity of molasses produced is the main result.

Having now separated the juice from the fiber, the chemist's attention may be concentrated on the former, and he is confronted with an aqueous solution containing about 15 per cent. of crystalline sugar and 3 per cent. of organic and inorganic impurities, out of which he is to extract as much sugar in as pure and dry a form as possible, and for as little money as possible. Two means of solving this problem present themselves: He may rely on the natural tendency of the liquor to crystallize, and to help this proceed to clarify the juice and then evaporate it, or he may precipitate the sugar from its solution in combination with lime, strontianite or baryta, and subsequently decompose the saccharate.

We know by experience that the first method is the one that is commercially valuable, and that the second one may be used on the final molasses only, after as much sugar as possible has been extracted by crystallization; the great bulk of the saccharate precipitate is the main difficulty in the way of this process, which is chemically very perfect.

The clarification of the juice is a matter on which the attention of chemists has been steadily concentrated now for forty years, without, as I have already said, materially altering the process of Perier and Possoz, who added an excess of caustic lime to the juice, allowed this to settle, thus producing a partial clarification, and then precipitated the greater part of the lime dissolved in the juice by carbonic acid gas. Later on, Jelinek pumped in the gas without waiting for the settling, and precipitated the whole mass together, precisely what we do to-day. The operation is repeated more than once now, and a very clean, clear filtrate is produced, with, however, a considerable expenditure in labor and machinery. It is a violent remedy considering the small amount of impurities we have to deal with, but it is our only one. Its principal defects are the great quantity of lime needed (equal to 3 per cent. on the weight of the raw material), necessitating special limekilns and involving voluminous precipitates, whose separation from the filtrate needs pressure filters of great size and strength, and whose washing free from sugar means more water to evaporate.

The efforts that have been made to replace this clarification have been various in kind, and many in number, but only those which tend to produce a similar precipitation in the presence of the impurities with other reagents have had any success. Very beautiful liquors may be produced by the action, for instance, of lead acetate, of alumina, of soluble phosphates, of tannic acid, etc., but the practical sugar-maker has never been able to see wherein an improvement lay over the ancient carbonatation process. This process is generally described as an entanglement of the impurities in the falling calcium carbonate, but it may be looked upon as nothing more than a mechanical filtration of a very perfect kind, in which the filtering medium is moved through the liquor instead of the liquor being forced through a cloth, or whatever may be used. It is possible, that by bearing this in mind, we may see our way to avoiding some of the troubles we are now afflicted with, and by performing a similar operation in such a way that a more intimate contact may be arrived at between the liquor and the falling carbonate, as good a result with less expenditure of material may be arrived at.

In cane sugar-houses the elaborate systems of clarification by carbonation and filtration have been tried and found wanting, for we find that by the action of a very small quantity of lime, and some heat, so great an effect is produced, that what would be gained by more perfect work from a purely chemical point of view would be lost commercially, owing to the extra time and apparatus needed. We are much nearer to the solution of the defecation problem in cane sugar, than in beet sugar-houses. Some work which I have carried on for a couple of years in Cuba, leads me to believe that a continuous and almost automatic clarification of cane juice, at a low temperature may be brought about, by extremely intimate mixtures of the lime and juice in exact quantities, but it would appear that the raw beet juice is too refractory a material to yield to such simple treatment.

The chemist's mind has turned of course with some hope to electricity, for the clarification of juice, and many and exhaustive have been the trials which have been made with this ghost-like element. Great corporations have erected large plants to test the possibility of separating the impurities from the raw juice of the cane and the beet by electrolysis, with the result, as far as the general sugar public know of demonstrating that while a great purification takes place it costs too much horse-power to effect it. These results, however, should not deter the chemist or electrician from further investigation, for it is quite possible that after the great mass of the impurities are removed, we may effect something by the application of the current to concentrated solutions?

In investigating the various methods of clarification, it has been customary to look to the removal of impurities as the standard of value. That is to say, the proportion of sugar to total solids dissolved in the juice is determined before and after clarification and the difference noted. This proportion, the coefficient of purity, as it is called, is the great guide of the sugar-maker for want of a better one. It is manifest, however, that when the quality of the impurities present is not considered, liquors of the same coefficient are not of the same value, and this leads to many errors in the treatment of the juice. Inasmuch as the object of removing impurities is to facilitate crystallization, we ought to attack those substances which give rise to a viscous or gummy condition of the liquor. All our efforts in fact should be directed to producing a medium in which the crystals may move with ease, and I may say, that for some time past I have abandoned tests for everything but viscosity with extremely encouraging results.

The less viscous a liquor is the more perfectly will it filter, and the filtration of liquor is the most important part of its treatment. Could we take the raw juice from the cane or beet and filter it cold through a dense medium, I doubt whether any further clarification would be necessary, and in well-conducted sugar-houses the greatest care is now taken to produce liquors free from any suspended matter. Five or six different filtrations of the same liquor may now be seen in many beet sugar-houses, but I believe that the mechanical treatment of the juice is only beginning to be understood, and is destined to play a much more important part in sugar manufacturing as well as in other industries. We know now only the use of a filtering medium, through which a liquor passes under pressure leaving impurities on one side; we have yet to observe the action of masses of suspended matter in an extremely minute state of division and brought into contact with the liquor by mechanical means. Mechanical filtration has already wrought one great change in the manufacture of raw sugar, that is, the total suppression of the use of bone charcoal and all its attendant cost and discomfort. Some refineries even are now working high-grade sugars without char, being enabled to produce a cold filtration of heavy liquor through the use of infusorial earth. The passage of this finely divided siliceous matter through the liquor effects the mechanical filtration which the cloths on the filter presses complete. I would strongly recommend the intending investigator to turn his attention towards the production of a substance in the finest possible state of division, and to apply this to liquors which are to all appearances filtered already. In this work the microscope might be used to great advantage. It has yet to play its part in the examination of sugar liquors, and this part may be a mighty one.

I must now turn to the main work of the sugar-house, for which the clarification is a preparation, viz.: the crystallization of the sugar out of its watery medium, and may pass over the reduction of the juice from its content of 18 per cent. solids and 82 per cent. water to 50 per cent. solids and 50 per cent. water, inasmuch as this is an engineer's problem, and presents few chemical aspects of importance. The continuation of the evaporation, however, in the vacuum pan, where the water is reduced to 5 or 6 per cent., presents a fine opportunity for the study of crystallization, a phenomenon of yearly increasing interest to the chemical world at large. The way the liquor behaves in the pan is the final test of the value of any method of clarification and a check on some methods of extraction. Over 80 per cent. of the total yield of sugar is obtained in this operation, and its proper carrying out is, therefore, of great importance. The study of the effect of high and low temperatures in the steam coils and in the body of the pan affords to-day a very excellent field for investigation. There occurs always in the boiling of the liquor in a vacuum a mysterious and considerable loss of sugar, caused probably, in part, by the action of the heat on the concentrated solution and by entrainment, or the flying of small globules of concentrated liquor upwards to the condenser. As regards the first, much uncertainty exists. As a rule nowadays, steam at about 10 pounds pressure or less is used in the coils for economy's sake, but when time presses, boiler pressure is turned on, and while the amount of available heat is not much greater, the transfer is more rapid from the coil to the liquor. Whether we really lose more sugar with a high temperature in the coils and rapid ebullition than we do at a lower temperature, when the liquor lies closer to the heating surface, is a matter which the chemist can well employ himself with. The excellent work of Dr. von Lippmann in this direction may serve as a basis for further investigation. While the question of entrainment is largely an engineer's problem in which the velocity of the vapor is the principal factor, certain observations made lately in Cuba have led me to believe that entrainment varies much with the nature of the liquor. There always occurs in boiling an entrainment of other matters than sugar, dissolved or suspended in the vapor, a sort of destructive distillation of the non-sugar, as it is called, and it would seem that this leads to a carrying up of crystalline sugar. Further, we do not know as yet whether the entrainment is affected by variations in the temperature and consequently the density of the escaping vapor, the velocity remaining constant.

When a strike of sugar is ready it consists of a mass of crystals, surrounded by a dense syrup, and may at once be centrifugalled, in which process between 60 and 70 per cent. of the weight of the masse-cuite is obtained in dry, raw sugar; or, it may be allowed to cool and crystallize further, in which case from 65 to 75 per cent. of sugar is recovered. A great deal of attention is now being paid to increasing this yield by stirring and cooling the masse-cuite simultaneously for several hours, and thereby promoting the growth of the crystals already formed. This would seem, on the surface, to be a very simple and logical process, but its carrying out requires much care, for there may easily be formed masses of minute crystals (technically known as false grain) whose presence is dreaded in the sugar-house, for either they retard greatly the work of the centrifugals or they involve a great loss by passing through the baskets with the molasses. At present the machinery in use is merely for a general agitation of the mass, but it has struck me that the directing of the flow of the mass in regular currents might greatly increase the regularity of the growth of the crystals. We have the well-known fact to start with, that a crystal will grow if it gets a chance at the expense of smaller crystals, and that a mutilated crystal, as observed by Wulf, will complete itself before other crystals are formed. The well-known work of Behr on crystalline glucose and, indeed, the daily practical experience at a vacuum pan seem to suggest that we may accomplish much by directing the path of the crystals in their journey through the mother-liquor.

After the greater part of the sugar has been centrifugalled out of the first masse-cuite we have to handle a molasses which contains about 20 per cent. of water and 50 to 100 per cent. of sugar in solution, the rest being inorganic and organic impurities. By evaporating some of the water—not too much—and either stirring the mass for a few days or letting it stand for a couple of weeks, a considerable quantity of second-grade sugar crystallizes out, leaving a lower grade of molasses. The simple thickening of this molasses the second time in the vacuum-pan will allow of still further crystallization, and whether this is done or more complicated means are resorted to, depends on the machinery at hand and the state of the market. The most successful chemical work of the last decade or two has been done in the treatment of the final molasses of beet sugar-houses. Cane sugar-houses produce molasses of a much lower content of crystallizing sugar, and containing a large quantity of invert sugar, which are usually edible, while the presence of great quantities of calcium and potassium salts in the beet molasses render them useless for food and difficult to handle in any way. By Dubrunfaut's osmosis process a quantity of these crystallizable salts may be removed and the sugar crystals allowed to form, or, by the various saccharate processes the sugar may be combined with the alkaline earths and precipitated from its solutions. These are very beautiful processes chemically. But in all of them, and particularly in a case of strontianite, a great deal of machinery is needed, and the low price of sugar is rendering their use very doubtful from the commercial standpoint. It seems strange that given a material which, when evaporated to dryness, contains 50 per cent. of sugar, we cannot induce a crystallization without the expenditure of so much power. Very many attempts have been made to accomplish this by reintroducing the final molasses into the sugar-house, mixing it with the raw juice and carrying it right through to the end; but this must, after a time, produce a mother-liquor of impracticable bulk. The solution of the problem perhaps will come with a greater knowledge of the crytalline life (if I may use such a term) of an impure sugar solution, and how to mechanically assist the straining for union of the widely separated particles.

The limits of this paper do not admit of my dealing at any length with the main problem of the refining of raw sugar, which is its decoloration, and which we may say is produced entirely by the use of animal charcoal. In spite of hundreds of patents for other means, the work of Derosne and Dumont has stood for seventy years or so, as I have already stated. Nobody has been able to produce artificially a means of exposing so advantageously the fine particles of carbon to the action of the liquor as the curious phosphatic skeleton of the bone affords us, allowing us, as it does, at the same time to collect so easily the carbon from the liquor after use and revivify it. There is no field of research which might perhaps repay the investigator better than that of the decolorizing of sugar-liquors, but anybody who undertakes this had better post himself thoroughly in the literature of the subject, for many surprising laboratory results have been obtained already whose practical value is nil.

I may say, in conclusion, that whatever process a chemist may evolve for the improvement of the sugar industry must be subjected to the most severe practical tests before its adoption will be even considered by the manufacturers in general. All raw sugar-houses now work at very high pressure. They differ from other manufacturing establishments in that they are idle a great part of the year, and they must work at all speed for a few months to get through their perishable raw material. Even a few hours' stoppages may entail a serious loss, and therefore speed and smoothness are primary considerations in the working of any new process. I believe there is a case known of an irate planter, whose work was delayed by a new process, using dynamite one fine morning on the apparatus to clear the path for the resumption of his old system.

Further, the actual value in dollars and cents must be clearly set forth, or the discoverer be satisfied with the scientific value of his work only. Sugar-makers are every day getting pretty circulars about how to get all the sugar out of the raw juice as first product, and similar impossible things, but business-like statements of income and expenditure are rare indeed.

Mining and Metallurgical Section.

Stated Meeting, October 12, 1898.

ANTHRACITE COAL IN PERU.

BY WILLIAM GRIFFITH, C.E.,
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Anthracite coal has for a long time been known to exist at various points in the Andes Mountains of Peru, and is mentioned in the writings of Peruvian authors and travelers. Up to the present time, however, there has been no use for it, locally. The silver mines, which are plentiful, have always been worked in the most primitive way and never below water level, so that there has been no necessity for steam fuel. Lignite, which gives a flame and is abundant in some places, has been preferred for roasting ores in the lixiviation process, which is the method most extensively in use for the extraction of silver. The climate is such that no artificial heat is required for warmth, and a few sticks or handful of charcoal is sufficient for the primitive methods of cooking in the mountains. There has, therefore, until recently, been no effort made to prospect or in anywise develop the Peruvian coal; consequently, but little is known in Peru of the extent or value of the fields of anthracite in the Andes.

We were called upon, during the past year, to make a hurried investigation of the coal resources of a vast area in northern Peru, and this paper is composed in part of extracts from our report.

TOPOGRAPHY AND CLIMATE.

The region along the coast of Peru is mostly a desert plain for about 20 miles in width, and to the eastward of this rises the precipitous wall of the Andes Mountains. Near to the coast the climate is temperate and delightful, a continual breeze from the ocean rendering the temperature very regular, as it averages about 70° the year round, occasionally running as low as 65°, and seldom rising higher than 80° in the middle of the day. It seldom or never rains, and the sun shines continually the year round. Of course, this condition of climate prevents the growth of vegetation along the coast. The only tree which grows spontaneously is the Algaroba, which is a hard, tough wood similar to locust, and is used largely for fuel, both for domestic purposes and for power. The soil on this strip of coast land is very fertile. When cultivated by means of irrigation from the streams which flow into the Pacific, it produces luxuriantly all sorts of tropical fruits, rice, sugar-cane, corn, potatoes, yuca, barley and other grains. The climate in the interior portions of the coast land not reached by the tempering winds of the ocean, is somewhat hotter than on the coast, the arid condition existing even to an elevation of about 9,000 feet above the sea.

Passing beyond the limits of the desert land, we come to the foothills of the Andes Mountains. The mountain plateau back of them is about 12,000 feet in height, with the sides toward the ocean deeply plowed by the rugged, precipitous cañons which are cut in their sides by the streams which find their way to the ocean.

Within the limits of the region in question, the following principal streams have their source in the Andes and flow westward to the Pacific, namely: The Chancay, the Sana, the Jequetepecque, the Chicama and the Moche Rivers. These streams, during the wet or summer season, are raging mountain torrents, carrying a large quantity of water. They are impassable and dangerous to ford during this season, but during the dry season of the winter time they become very low, so that oftentimes the water is all taken for irrigation purposes, and none reaches the ocean.

The table-land of the Andes is reached only by means of the narrow, crooked trails, which wind about or up and down over the rocky and precipitous mountain slopes and ravines, which are in places more or less dangerous. These trails can be traversed on horse or mule back, which is the only means of access to the interior. There are two or three railroads which extend from the coast at Pacasmayo, Eten and Salaverry up the comparatively flat valleys of the larger streams, a distance of 30 or 40 miles, reaching an elevation of about 3,500 feet above tide. None of them, however, are extended up the precipitous slope to the top of the plateau.

After once ascending these steep mountain sides, we find at an elevation of about 10,000 or 12,000 feet, a totally new and entirely different condition of affairs from that which obtains on the coast. The surface has an average elevation of about 12,000 feet. It is covered thickly with a succulent grass known locally as the pampas grass, which grows a foot or 18 inches high, and is a most excellent food for cattle. The surface of the country is much broken and very irregular. Multitudes of mountain peaks are to be seen stretching up from 500 to 2,000 feet above the general level, while the limpid streams which are formed by the copious rains of the wet season, and the occasional showers of the dry season, cut deep channels for themselves through the surface of the plateau. The valleys of these streams, while often steep cañons containing a more or less luxuriant growth of small trees, bushes, ferns, vines, etc., are occasionally broad, fertile valleys which are doubtless susceptible of extreme cultivation. The climate on this mountain plateau during the wet season, is extremely disagreeable and stormy. It rains nearly every day, which causes the trails to become muddy, slippery and extremely dangerous, particularly on the precipitous mountain slopes. During the dry season the weather is very pleasant and averages about 60° at mid-day, and in the higher altitudes, during the night, about 40°, although it occasionally falls as low as 32°. The soil is exceedingly fertile, and in many places can be cultivated without irrigation, producing abundantly, crops of potatoes, alfalfa, corn, wheat and other grains; but owing to the lack of transportation very little land is cultivated except by the Indians on the small gardens or farms around their huts.

This plateau is divided into two parts by a longitudinal ridge about 90 miles distant from and parallel to the coast, having an elevation of 13,000 feet, and with an occasional peak towering far above. This ridge forms the Continental

Divide of South America. The streams previously mentioned, drain the western slope, while the eastward slope is watered by the many streams which flow eastward and northward into the Marañon River, which may be considered as the main source of the central trunk of the Amazon River system. In this vicinity this stream is said to be a swift mountain torrent flowing in a rocky cañon, its course being nearly north, parallel to the coast.

GEOLOGY.

The geology of this territory, as observed in a hasty way while traveling along the precipitous trails, would seem to consist mainly, near the coast, of a thick formation of red and buff shales apparently of the triassic age. These sandstones and shales are cracked and ruptured in numerous places by dikes of granite, trap and other igneous rocks. They are apparently surmounted in the interior by the more recent rocks of the jurassic, cretaceous or tertiary age, consisting, first, of great thickness (2,500 feet in places) of fine-grained, light-gray or white altered sandstone, approaching quartzite. Overlying this is considerable thickness of softer sandstone, red, yellow and buff shales and black slates, and this is again capped by measures consisting largely of a very thick formation of limestone which, in the vicinity of Hualgayoc and Bambamarca is apparently several miles in thickness and contains many fossil shells of recent age. All of the above formations are most beautifully stratified, and their high and vertical cliffs present a picture delightful to the eye of the geologist.

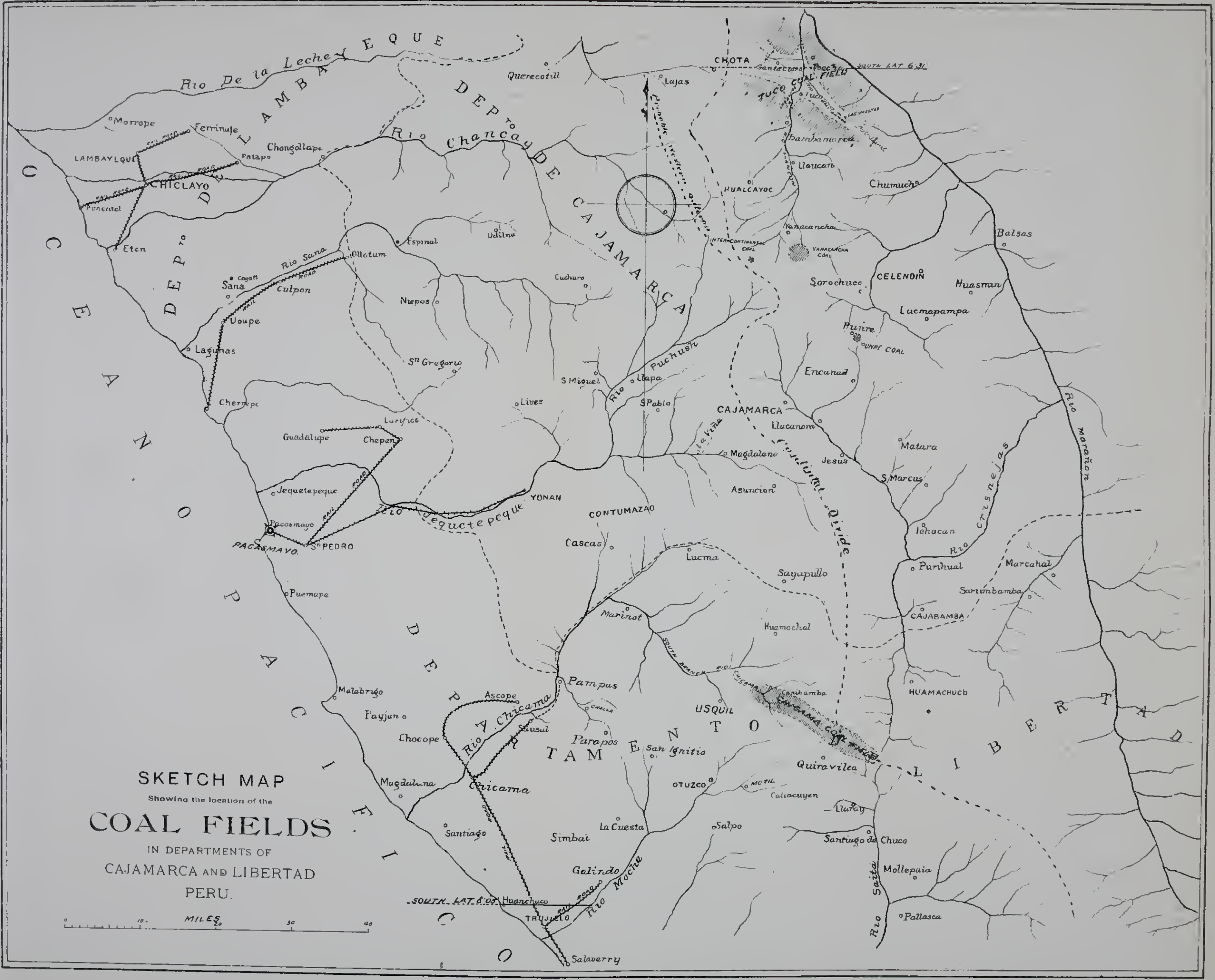
While the above presents a general idea of the formation of the mountains, the rocks are by no means regularly disposed, being ruptured and distorted in a marvelous manner in places, by the fierce volcanic action which has prevailed in past ages. The cañons cut into the western slope by the streams flowing towards the ocean, present a marvelous picture of rock stratification, showing the formation to be twisted and contorted in all directions, while the eruptive rock consisting of granite, trachyte, porphyry, and all sorts of breccia, tufa, etc., is visible at every turn, and immense dikes and high mountains of igneous rock are visible scattered about all over the area covered by this territory. Where these dikes have forced their way, the upheaval and distortion of the underlying rock formation due to this volcanic action is plainly to be seen. In some parts these disturbances are more marked than in others; great mountains of trachyte, granite, etc., tower 1,000 or 2,000 feet above the plateau, while in other places the regular sedimentary formation still remains nearly normal, only slightly tilted from the position in which it was originally deposited. In these latter portions of the plateau the stratification is oftentimes quite regular and free from volcanic rupture.

The rock formation where not so much disturbed by volcanic action, is disposed in a series of large basins and saddles. The axes of these saddles or anticlinals have a general direction from the northwest to the southeast. A longitudinal section of the mountain range parallel to the coast would probably show these basins and saddles following one after the other, giving a wavy appearance which would be very much distorted and twisted in the region where it is much disturbed by the upheavals due to the eruptive rocks. Where these basins are very deep we would have them filled by the sandstone and limestone of the more recent age, which are more or less eroded or washed off from the crests of the upward rolls or anticlinals.

COAL FIELDS.

The formation containing the coal beds which occur in this territory is the one described above as a light-gray altered sandstone, to be found 1,000 or 2,000 feet under the limestone referred to before. We would therefore expect to find outcrops of coal where the anticlinals or saddles are of sufficient prominence to raise this formation to the surface, and the coal beds to be in condition for economical mining where the volcanic action was so slight that the stratification is not too much distorted or broken, thus allowing the coal beds to exist in a normal condition, free from the faulting and crushing which would result from fierce volcanic disturbance.

There were two principal regions examined. The one which we shall, for the purposes of this paper, call the Northern or Tuco Field, is located in the northern part of the Department of Cajamarca, about 50 miles north of the ancient Inca City of the same name. The other, about 100 miles south of the first, in the Department of Libertad, which we will denominate the Southern or Chicama Field. To reach the northern field we start from the port of Pacasmayo, on the Pacific Coast, with half a dozen saddle mules and a dozen pack donkeys laden with our provisions, tents, tools, etc., and travel inland about 100 miles, ascending and crossing the Andean plateau and continental divide at an elevation of about 13,000 feet to the town of Hualgayoc, which is located in the bottom of a deep valley about 6 miles to the eastward of the crest of the divide. This town, an ancient and curious one, is the center of a large silver mining region, and the valley is watered by a small mountain torrent flowing eventually to the Amazon, and is enclosed on one side by a high precipitous mountain of beautifully stratified limestone of recent age, containing numerous fossil oyster or other recent shells. The eastward dipping outcrop of this limestone was crossed by the trail several miles before the summit of the divide was reached. The other side of the valley is formed by two large mountains of trachyte, which compose part of an immense upheaval or dike of volcanic rock which extends 20 or 30 miles and forms the Hualgayoc mineral belt, from which silver, copper and other metals have been mined for years by the present inhabitants and their ancestors of the Inca race. From Hualgayoc we traveled northward down the valley of the stream, which soon unites with Rio Llaucon, a branch of the Mariñon, which latter forms the source of the main trunk of the Amazon River system. We continue down the Llaucon for about 30 miles, the main trail leading now along the bottom of the narrow valley and now winding over or round the precipitous mountain ledge. After leaving the igneous rocks of Hualgayoc, our journey lies almost the whole distance over the recent limestone formation previously mentioned, which dips southwestward at an



SKETCH MAP

Showing the location of the

COAL FIELDS

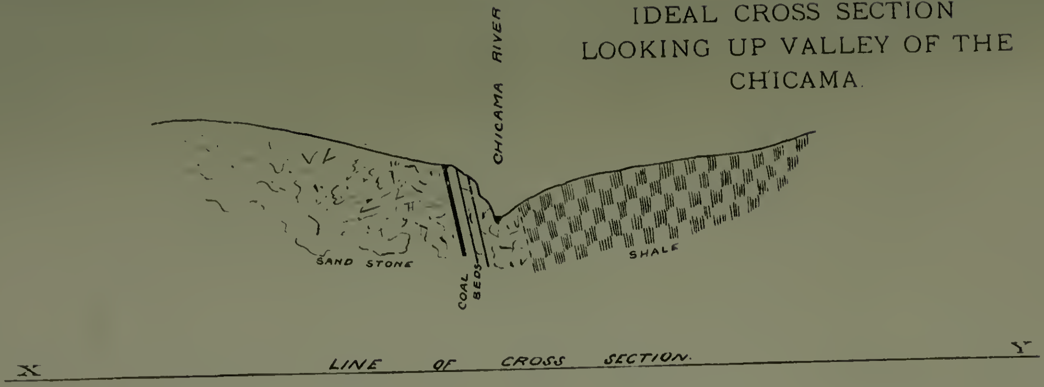
IN DEPARTMENTS OF

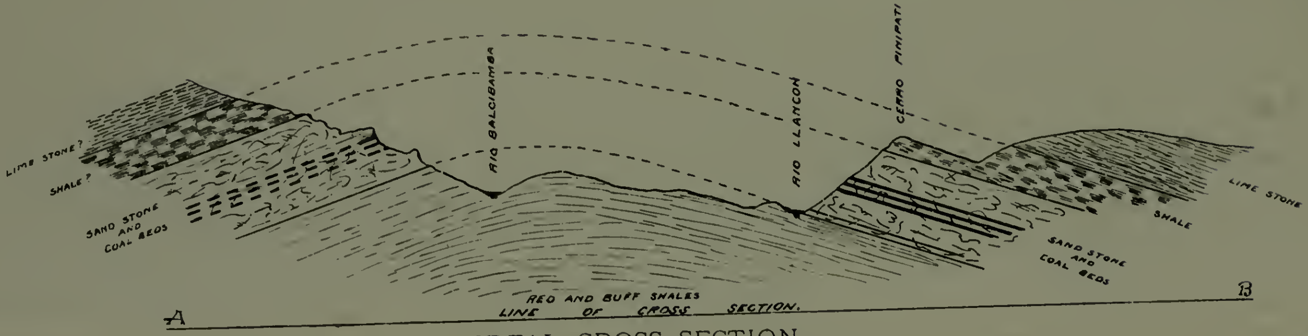
CAJAMARCA AND LIBERTAD

PERU.

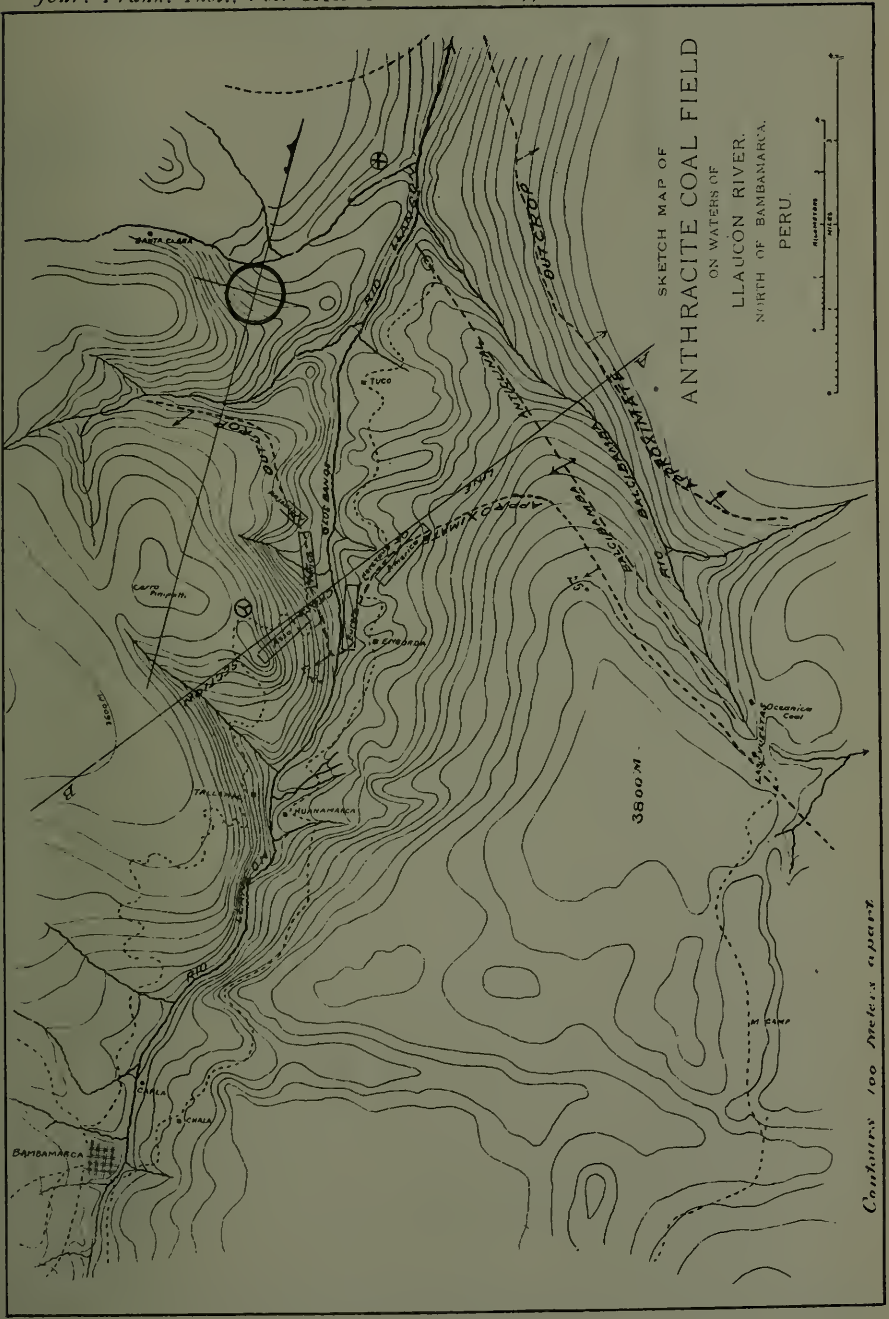
Jour. Frank. Inst., Vol. CXLVII. March, 1899.

IDEAL CROSS SECTION
LOOKING UP VALLEY OF THE
CHICAMA.



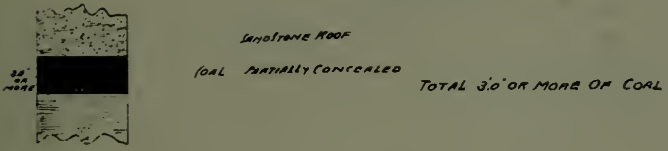


IDEAL CROSS SECTION.
LOOKING UP VALLEY OF THE
BALCIBAMBA.

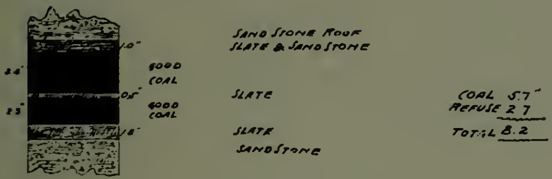

SKETCH MAP OF
ANTHRACITE COAL FIELD
ON WATERS OF
LLAUCON RIVER.
NORTH OF BAMBAMARCA.
PERU.
KILOMETERS
MILES
Contours 100 Meters apart
SANTA CLARA
TUCO
OUTCROP
ANTICLINAL LINE
APPROXIMATE
RIO LLAUCON
RIO BALDAMBA
Cerro Pinipotti
ENCORADA
HUANAMARCA
TALLAMAC
3800 M
3600 M
Oceanica Coal
LA VUELTA
M CAMP
CARLA
CHALA
BAMBAMARCA
America
B

SECTIONS OF TWO COAL BEDS ON EAST SIDE OF LLAUCON RIVER OPPOSITE LOS BAÑOS.

Nº5



Nº6

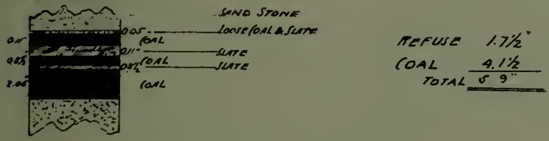


SECTIONS OF COAL BED

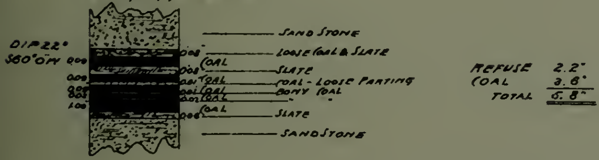
—AT—

LOS BAÑOS.

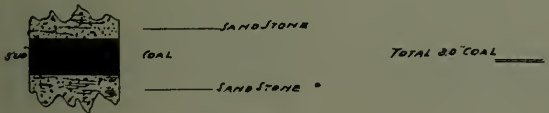
Nº 1
Near Entrance Of Drift



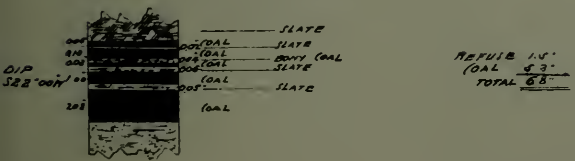
Nº2
In Face Of Drift, 95 From Entrance



Nº 3



Nº4
At Outcrop of Upper or Nº 4 Bed Drift



SCALE. 1 IN—18 FT

inclination of about 25°, and is evidently of enormous thickness. We, however, eventually pass below it and our route extends over several miles of the red and buff shales and gray sandstone with an occasional seam of black fireclay or slate, all dipping southwestward conformably with the limestone. We now find ourselves high on the precipitous mountain side above the river, and we descend by a steep and dangerous trail about 3,000 feet to the bottom of the valley. While passing down we note that the mountain sides are now composed of a fine-grain light gray altered sandstone or quartzite, very hard and very regularly stratified, all dipping about 22° southwesterly. It is near the base of this mountain, about 600 feet above the stream, that we find exposed in the cliffs three beds of fine anthracite coal. This locality is known locally as Los Baños, on account of the warm or hot alum springs which are found at the base of the mountain, formerly doubtless used as a bathing spring. The coal beds are about 50 feet apart, and are respectively 5½, 3 and 6½ feet in thickness, having about the same proportion of slate and interstratified refuse as is common in our Pennsylvania anthracite. The sections of these seams, as measured in some old openings cut in the seam years ago, which are still accessible, are shown on the plate following; that is, No. 1. Other exposures were subsequently noted in the cliffs across the river, a mile distant, which were also measured and are represented in *Plate No. 2.* They are doubtless continuations of the same beds. The coal can only be seen where naturally exposed in the nearly vertical cliffs or washouts along the stream, since the tropical foliage is very dense, and no attempt at prospecting has ever been made. An examination of the topography and geology of the vicinity resulted in the following facts:

About 2 miles further down the Llaucon River another stream, known as the Balcibamba, unites with it, flowing in from the southeastward through a deep valley. The mountains on each side of these two valleys are formed by the thick sandstones of the coal measures, causing high, precipitous cliffs. All the measures to the southward are noted to dip to the southwest, while those forming the northward side of the Balcibamba Valley dip to the northeast, thus disclosing the fact that the valley of the Balcibamba now follows the axis of an immense anticlinal, the crest of which has been eroded so that the bottom of the valley is now composed of a series of softer red and buff shales and broken sandstone which underlie the quartzite containing the coal. While these coal-bearing sandstones on either side of the anticlinal seem to be very regularly disposed as to strike, dip, stratification, and not much disturbed by volcanic influences, the softer measures underlying them along the anticlinal appear to be disrupted, upturned and much more contorted, which would seem to point to the anticlinal valley of the Balcibama as the center line of greatest disturbance in this immediate vicinity. Standing on a prominence in the valley, the beautifully stratified and regularly dipping rocks of the coal measures may be seen forming the cliffs and mountain tops as far as the eye can reach on either side. We followed the trail leading up the valley of the Balcibamba for 15 miles or thereabout, passing eventually above the sandstone of the coal measures to the rocks of the overlying limestone. Other exposures of coal were noted along the trail; those near to the center of the anticlinal being much disrupted and crushed, while those located further away from the line of disturbance were in much better condition, the coal apparently being of good quality and the bed regular. It must be evident that if these coal beds are as continuous in the measures of the Andes Mountains as coal seams usually are in other parts of the world, that here is a vast coal field with outcrops flanking the mountains for 15 or 20 miles or more on both sides of the Balcibamba and the Llaucon Valleys, and even extending southwestward in the direction of the anticlinal to or across the Mariñon River. So far, our investigation has discovered that this coal field would be composed of two parallel basins extending northwest and southeast, separated by the anticlinal of the Balcibamba Valley. The one basin dipping to the northeast for an unknown distance under the mountain, and perhaps having its northern margin somewhere near the junction of the Llaucon and Mariñon Rivers. The other basin dipping to the southwest under the limestone measures forming the continental divide between Hualgayoc and the town of Chota. Future explorations may discover its southwestern outcrop 20 miles or more distant on the Pacific slope near the head waters of the Rio Chancay. In some parts of this latter outcrop, however, fierce volcanic action has prevailed which would tend to seriously affect the economic value of the coal seams. So far as we know at the present time, no economical coal beds have been uncovered as yet on the Pacific slope in this northern field. At the southernmost point where our trail crossed the outcropping measures on the Pacific side, indications of coal were prospected, but as the region was much disturbed by the eruptive rocks, the prospect was found to be worthless.

As before stated, the coal bearing quartzite at Los Baños are about 3,000 feet thick, whereas the coal beds mentioned are found near the bottom part of these measures, and the 2,000 feet of overlying rocks were not examined. There is, therefore, a possibility of the existence of other economical beds higher in the measures, which would be revealed by careful prospecting. The country is very sparsely inhabited by a few natives to whom the coal is of no use. They, therefore, attach no more value to it than to the other rocks of the mountains, and have accordingly made no attempt to uncover the coal. Exposures, therefore, are few.

As to the quality of the coal in this northern region, we refer to the Analysis No. 1 below. We may say that the sample from which this analysis was made consisted of a number of pieces from all the openings in Veins No. 2 and No. 3 at Los Baños. These were the only ones which furnished proper samples for analysis, and while we had no opportunity to make a proper sample from the total height of the bed, still, this analysis will probably furnish a fair criterion in which to judge the quality of this coal.

We would call attention to the high specific gravity of this coal. The anthracite coal of the Wyoming and Lackawanna Valleys in Pennsylvania would average about 1·5 specific gravity, whereas this coal, as determined by Mr. McCreath, and also as determined by us, runs from 1·62 to 1·65 specific gravity, which is a very good feature, indeed. We regard the anthracite of this northern coal field, as far as we have been able to judge, equal to the average anthracite of Pennsylvania, as will be shown by Analysis No. 1 following, by Mr. McCreath, of Harrisburg.

ANALYSIS No. 1.

Water	1·450
Volatile matter	5·633
Fixed carbon	83·620
Sulphur	·554
Ash	8·743
	100·000
Specific gravity	1·62

THE SOUTHERN FIELD.

The second anthracite field visited, which we have previously called the Southern Field, may be approached by the trail leading inland from the city of Trujillo on the Pacific coast, about 60 miles southward from Pacasmayo. This trail passes up the cañon of the river Moche to the town of Otuzco, thence over a summit to the head waters of the south branch of the Chicama River in the Department of Libertad. It is in this latter locality along the upper Chicama that we find the coal. The waters of this stream flow to the Pacific at a point about 15 miles northward from Trujillo, and the coal fields are about 100 miles southward from the northern field just described and about 80 miles inland from Trujillo and a little more than 100 miles from Pacasmayo. Our trail first enters the field in the valley of the stream at about 9,000 feet elevation on the westerly slope of the Andes, and we are able to follow the measures for 15 or 20 miles, and probably much further to the southeastward, to the summit of the Continental Divide, or even as far as the head waters of the Santa River, which flows into the Pacific near the bay of Chimbote. The south branch of the Chicama is here a very rapid mountain torrent, flowing in a deep valley with sloping sides, which rise to the height of about 13,000 feet, and it is in these mountains, partly on both sides, but mostly on the northern side, that the coal is found. The strike of the measures is north 50° west, the same as the course of the stream; the average dip of the rocks is very steep, being 70° to 80° in a southwesterly direction. The coal-bearing rocks here seem to be the same sort of hard altered sandstone in which we find the coal in the northern field, although the formation is more distorted by volcanic action, which is quite evident and prominent in some portions of this southern field. At the point where we entered the valley the coal-bearing rocks were to be found on both sides, but further to the southeastward, that is, up stream, they occupied the flank of the mountain on the northerly side of the valley, which was more precipitous than the opposite side, which seemed to be composed mostly of a softer formation, consisting of dark slates and shales regularly stratified, containing numerous shells of recent age, although we saw no limestone in this vicinity. We were unable to trace the existence of any regularly formed coal basin; the dip seemed to be all one way—southwesterly, and over the mountain to the southwestward of the coal measures the formation changed to the eruptive rock so common in this portion of the Andes, thus apparently breaking off the continuity of these measures to the southwestward. The coal beds in this neighborhood are quite large and very prominent, and owing to the steepness of the dip, the soft material of the outcrops have been eroded by the continual rains of the wet season, thus forming long troughs or depressions, which may be easily traced. The beds seem to extend with a fair degree of continuity for a distance of at least 15 or 20 miles, and in all probability much farther. We had information of coal beds being uncovered several miles to the westward and over the divide to the southeastward, beyond the limits of the territory examined; there were numerous exposures to be seen, particularly on the northerly side of the valley, many of which had been opened by the natives, who use the coal for blacksmithing, and so on. These openings were mostly confined to what appeared to be one or two mammoth coal beds opened at various points. The first of these is situated in the mountain side of the southerly side of the valley at an elevation of about 10,000 feet above tide, on a branch of the main stream. At this point there are two or three beds visible, one of which was being mined and the coal transported several miles to a silver works, where it is used for roasting silver ore. Other smaller beds, about 3 feet in thickness, were located about 100 feet apart lower down in the measures. The principal bed, however, a measured section of which is given on *Plate 3*, section *A*, seemed to be a very fine seam. This bed of coal, about 6 feet thick, occurred lying between well-defined walls of hard white sandstone. The walls were separated about 15 feet apart, and the erosion of the softer measures contained between them formed a great ditch or trough, which could be plainly seen ascending the mountain several hundred feet, and also descending and crossing the branch cañon, though the seam was evidently much thinner near the bed of the stream. This opening was about 500 feet up the side of the cañon. This same bed was opened at another point higher on the mountain side, which was closed at the time of our visit. The coal from this latter opening was described to us as being very soft and friable, and was dug out with a shovel and carried on mule backs to the silver works, several leagues away, where it was mixed with a percentage of clay, made into balls, and, after drying, was used in this form for roasting silver ore. This mine was said to have been driven 300 or 400 feet into the mountain side. It was near the top of the mountain, which was, possibly, the reason at this point for the crushed or disintegrated coal, or, as we would call it in the anthracite region, a dirt fault. These dirt faults are quite common in the Schuylkill region of Pennsylvania, and are expected and met and overcome in the ordinary course of mining in that field.

The second important opening was about 3 miles further up the stream, close to the level of the creek. Here a fine bed of coal 10 feet thick was found, a measured section of which is shown on *Plate 3*, section *B*. The elevation of this coal opening was about 9,300 feet, with a strike about 50°

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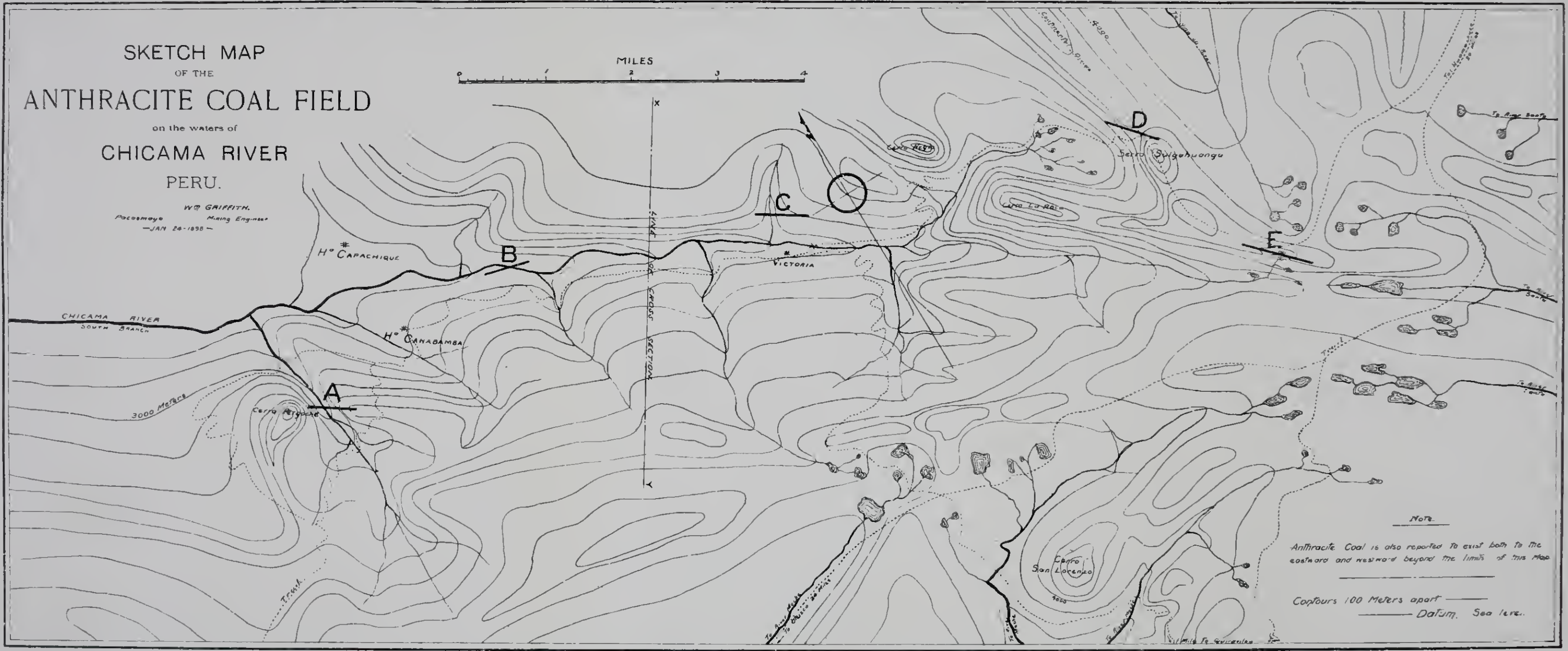

SKETCH MAP
OF THE
ANTHRACITE COAL FIELD
on the waters of
CHICAMA RIVER
PERU.

W^m GRIFFITH.
Pacasmayo Mining Engineer
—JAN 24-1898—

Note.

Anthracite Coal is also reported to exist both to the eastward and westward beyond the limits of this Map

Contours 100 Meters apart
Datum. Sea level.

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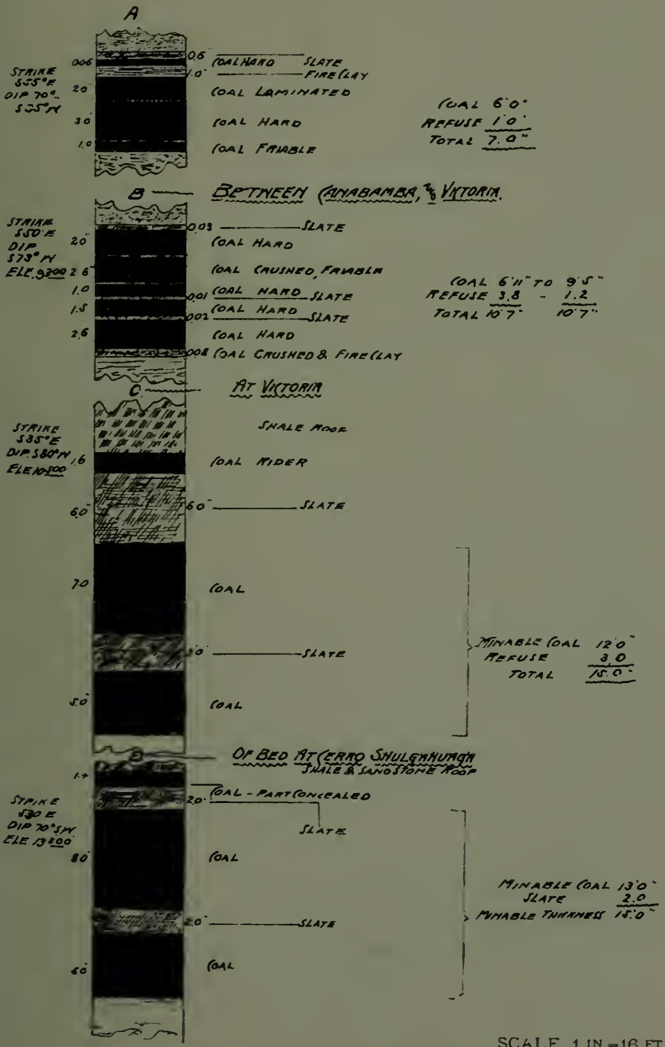
SECTIONS NEAR CANABAMBA AND VICTORIA ON SOUTH BRANCH CHICAMA RIVER.



SCALE, 1 IN.=16 FT

southeast, dipping 73° to the southwestward. This bed is a very fine one, being nearly all pure coal, the only poor feature being a stratum of soft or crushed coal 2½ feet thick. This, however, may change to firm coal at other parts of the bed. This fact, however, could only be proved by the actual course of mining. Benches of crushed coal are quite common in the Schuylkill region of Pennsylvania, where, even including this crushed stratum, this bed would be considered a very economical and profitable bed to work. As in the other cases noted in this coal field, the beds were enclosed by walls of hard sandstone, smooth and straight, and the ditch or trough formed between these walls at the outcrop can be traced ascending the mountain on the other side of the creek to the southeastward. Also smaller depressions indicating the presence of other coal beds of various thicknesses parallel to and both overlying and underlying this mammoth bed, can be readily traced. About 3 miles further up the stream another opening has been made into this mammoth bed. At this point is the lixiviation plant, known as the Victoria Silver Works. The ore is here roasted by means of the anthracite coal taken from this seam. A very primitive gas generator has been constructed and the gas is used to roast the pulverized silver ore. This coal opening has been worked for some time, the bed is evidently very large and fine, as can be seen from Section *C*, on *Plate 3*. It had, unfortunately, owing to the unworkmanlike manner of mining, caved in three days before the date of our visit; so that while we were unable to take a measured section of the bed the evidences of a very large, fine coal bed at this point were unmistakable. We were allowed to copy the measurements shown in Section *C*, from the report of an English engineer who had examined the silver works at Victoria. This opening is at an elevation of 10,300 feet; also in the side of a steep cañon cut in the mountain by a small creek, which flows at right angles to the strike of the seam, and empties into the Chicama, a short distance away. As far as the eye could reach on either side of the coal bed, the location of the outcrop might be easily noted by the immense gulley formed by the erosion of the outcrop. In the sides of this cañon the outcrops of other beds could also be noted, located 100 feet more or less apart, underlying the mammoth seam. The hills on both sides of the cañon are about 700 feet higher than the drift level, and the drift mouth was about 300 feet or thereabouts above the level of the Chicama. Several other exposures or openings into this seam were noted further to the southeastward at various points, separated several miles apart. One of these is located about 5 miles from Victoria on the crest of the Continental Divide, elevated about 13,000 feet above the ocean. The large outcrop gives evidence of a remarkably fine bed of anthracite. It can be plainly seen enclosed between high walls of quartzo-sandstone, which project 20 or 30 feet above the coal and form, as in other cases, an immense ditch 40 feet in width. The coal occurs in the soft measures between these sandstones, which extend for 2,000 or 3,000 feet along the mountain side. At the time of our visit some natives were loading the coal on donkeys for transportation to a distant village for blacksmith purposes. The full section of this bed could not be measured, as part of it was concealed, but the portion exposed to view, about 18 feet, is shown in Section *D* on *Plate 3*, and discloses a remarkably fine bed of anthracite coal. The openings referred to, to the southeastward to this point, which were not sufficiently enlarged to enable us to take the measurements of the sections, disclosed, however, the clear, clean anthracite coal, giving proof of the economical thickness and workable quality of the seams. As stated before, this same series of coal-bearing rocks, probably extend further to the southeast, as has been reported. We know, however, that coal dirt or blossom is brought from what was represented to us as a large coal bed located beyond the limits of our search, to the silver mining town of Quiravilca, and there made into balls by mixing with clay, for domestic use. Samples of coal were also shown to us from the northwestward extension of this same field, taken from another branch of the Chicama River, giving evidence of the extension to the northwestward of this coal field, far beyond the limits of the territory visited. As to the uniformity and continuity of these coal seams we will say we consider the measures here to be much more disturbed through volcanic action than in the northern field. Nevertheless, we believe that the evidences of continuity are sufficient to warrant the conclusion that an immense body of coal exists in this vicinity, which can be economically mined, and much of it above water level, even within the territory described; while the same measures unquestionably extend in both directions far beyond these limits. Samples of coal were taken from the openings mentioned, an average sample of which gave the Analysis No. 2 following, also by Mr. McCreath:

ANALYSIS NO. 2.

Water	1·596
Volatile matter	3·030
Fixed carbon	90·906
Sulphur	·652
Ash	3·816
	100·000
Specific gravity	1·67

From this analysis we should judge that the coals in this region are of unusual purity and excellent quality. For sake of comparison we give here an average analysis of Pennsylvania anthracite:

NO. 3—PENNSYLVANIA ANTHRACITE, AVERAGE OF 31 ANALYSES.

Water	3·277
Volatile matter	4·317
Fixed carbon	83·294
Sulphur	·600
Ash	8·514
	100·000
Specific gravity	1·59

It is impossible to make any reliable estimate as to the depth to which these coal seams extend. As stated above, they dip into the ground at an angle of about 70° and extend along the strike from the northeast to southwest from 15 to 30 miles or more. Owing to this dip, and the fact that the soft measures have been washed away from the outcrops it is much easier to open into the coal and follow the outcropping than in the northern field. And while the coal openings are more numerous and much more coal actually visible to the eye in the southern field, it does not necessarily follow that there is more minable coal here, because owing to the different mode of disposition of the coal, the outcrops in the northern district are more or less covered with debris and vegetation, so that they are not visible unless exploration is especially made for the purpose of uncovering them. And the beds are so disposed that they may be more cheaply mined.

We made a collection of the fossil plants which are to be found in the slates accompanying the coal beds, which have been submitted to experts of the Smithsonian Institute at Washington and elsewhere, and they have been able to state, perhaps, definitely, as to the geological horizon of the Peruvian coals. From the results of their investigations there would seem to be no doubt that these measures are of more recent age than the anthracite coals of the carboniferous measures of Pennsylvania or the Triassic coals of Richmond, Va., and are probably of Jurassic age and somewhat older than the anthracite and bituminous coals of the cretaceous formation in Colorado. Their position being thus mid-way, as it were, between formations containing economical coal beds of well-known extent and continuity, would seem to be favorable for an extensive deposit of coal in the region under consideration. In Colorado the anthracite coals are known to be more or less local in extent; that is to say, the bituminous seams are found overlying or underlying the seams of anthracite, in the same formation, while the same bed of coal may be anthracite in one place and bituminous in another. This is doubtless caused by the fact that the heat required to change the bituminous coal to anthracite, which was probably derived from the existence of eruptive rock near the coal seam, was more or less local in its effects, and apparently more intense in some places than in others; and the bituminous coal which in one place was undisturbed, in another part of the coal measures was converted into anthracite. We think we are prepared to say that this condition of affairs does not exist in the limits of this territory.

Throughout our travels we have noticed the unmistakable evidence of an intense heating of the rock formation in all portions of the Andes Mountains. The sandstones containing the coal, wherever we have noted their existence, have been unmistakably heated to an extreme degree, and there were absolutely no evidences of the existence of bituminous coal anywhere within these measures, so far as we have been able to ascertain. We regard the lignitic coal of Yanacancha and elsewhere as a deposit of a more recent age, and while we understand that coal of various kinds exists in other portions of the same region, not examined by us, we think it extremely doubtful that in any of these places will be found bituminous coal in the rocks of the same age which contain anthracite. We are, therefore, of the opinion that the anthracite coals of these fields will be found uniform in quality throughout the whole extent of the measures in which they exist.

HUAMACHUCO BASIN.

Our travels were continued to the ancient town of Huamachuco, on the eastern slope of the Andes. This town is located in the bottom of a wide, deep valley, evidently composed of the soft measures underlying the coal-bearing rocks. Capping the mountain on either side of this valley, the measures have the same appearance at a distance as those which covered the hills in the northern field described. Abundant rumors came to our attention of the existence of coal seams in the mountains adjacent to Huamachuco. No attempt was made to examine them, as they were evidently more or less inaccessible, and our time was limited. However, it is probable that economical coal beds exist here on the eastern side of the continental divide. The citizens of Huamachuco use the coal blossom from the anthracite seams of the valley for domestic purposes by mixing with clay, as before described. It is questionable, however, whether the beds near the town from which this blossom is secured are of economical thickness. It is highly probable that if proper time was given to exploration in this northern portion of Peru, other coal areas would be found within the region covered by this paper, and which are not known at present. From what has gone before, however, it would seem conclusive that there exists in the Andes Mountains of northern Peru a vast wealth of anthracite coal awaiting development for the supply of the coal market of the western coast of South America or along the Amazon River system.

THE SMOKE NUISANCE WITH SPECIAL REFERENCE TO THE CONDITIONS PREVAILING IN PHILADELPHIA.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts.*]

[No. 1963.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 12, 1898.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, to which was referred a communication of the Board of Health of the City of Philadelphia, requesting the co-operation of the Franklin Institute in reference to the proper regulation of the smoke nuisance in the City of Philadelphia, respectfully reports as follows:

The Franklin Institute has held two meetings devoted especially to the consideration of the subject of the abatement of the smoke nuisance from a scientific standpoint, at which meetings numerous engineers discussed the matter. These proceedings were published in full in the *Journal* of the Institute for June and July, 1897. In response to a general request, the discussion was resumed in September and October, when the various appliances in use for smoke prevention were illustrated and explained by many manufacturers. These data were printed in full in the *Journal* for January and February, 1898.

The Board of Managers of the Institute reported the following preamble and resolutions, which were adopted at the stated meeting of the Institute on September 15, 1897:

"WHEREAS, The Board of Health of the City of Philadelphia has requested the Franklin Institute to discuss the question of smoke prevention, and to offer practical suggestions relative thereto; and,

"WHEREAS, The use of bituminous coal for fuel is increasing in this city and is likely so to continue in the future; and,

"WHEREAS, It appears from testimony presented to the Institute that it is practicable to burn bituminous coal in suitably constructed furnaces without creating a smoke nuisance; therefore, be it

"*Resolved*, That it is the opinion of the Institute that the continuous or frequent discharge of dense black smoke from furnaces of stationary boilers is avoidable, and should not be permitted within the city limits.

"*Resolved*, That the emission of smoke from locomotives and furnaces other than those of stationary boilers might be greatly reduced if the co-operation of firemen and employers was enlisted with an earnest intention to abate the nuisance, and more especially could the railway companies be induced to use anthracite coal or coke in the furnaces of the locomotives used for local service in the train-yards within the city limits.

"*Resolved*, That a copy of these resolutions be sent to the Mayor, to the President of the Board of Health and to the Presidents of City Councils."

The sub-committee held numerous meetings, discussing the matter with the late Dr. Ford, President of the Board of Health, and Mr. Theo. N. Ely of the Pennsylvania Railroad.

After a careful consideration of all the data obtainable, the committee recommends that the following conclusions be referred to the Board of Managers for embodiment in the draft of an Ordinance to be transmitted to the Board of Health:

(1) The continuous discharge of dense black smoke from

stationary boilers using bituminous coal can be prevented by the use of appliances now well known.

(2) The discharge of dense smoke from locomotives using bituminous coal has not been shown to be preventable, and large volumes of smoke will probably continue to be produced from these boilers. Much of the nuisance would be abated should all drilling and shifting engines be required to burn smokeless fuel.

(3) The burning of soft coal in private dwellings produces smoke, but as the amount of soft coal so burned in this city is small, and is not likely to increase largely, the Committee does not regard this phase of the question as serious. Moreover, it has thus far not been found practicable to apply any mechanical device to prevent the formation of smoke in such cases.

It is the opinion of the Committee that a suitable smoke ordinance embodying the two suggestions herein, is not only desirable, but necessary, in order to prevent the gradual growth of a smoke nuisance; it is believed, moreover, that such an ordinance would not entail undue hardship upon any interests, and would not necessarily involve the city in much expense if put into effect before the evil complained of by the Board of Health shall have attained large proportions. Prevention in this case is better than cure.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, May 4, 1898.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

L. F. RONDINELLA,
Chairman Committee on Science and the Arts.

[The sub-committee which conducted this investigation was composed of Prof. H. W. Spangler, Mr. A. E. Outerbridge, Jr., Dr. Coleman Sellers, Mr. Wm. M. Barr, Mr. John Birkinbine.]

APPENDIX.

The Committee on Science and the Arts, having been charged with the duty of framing an Ordinance embodying the foregoing conclusions, to be submitted to the Board of Health, as expressive of the views of the Franklin

Institute, presented the following draft, which was approved by the Board of Managers, and ordered to be transmitted to the Board of Health; viz.:

A PROPOSED ORDINANCE to prohibit the frequent emission of opaque smoke from chimneys of boiler furnaces and from smoke-stacks of shifting locomotive engines, and declaring the same a public nuisance subject to penalty.

SECTION I. The Select and Common Councils of the City of Philadelphia do ordain: The frequent emission of opaque smoke from any chimney or smoke-stack of any boiler furnace within the corporate limits of the City of Philadelphia, shall be deemed, and is hereby declared to be, a public nuisance, and is hereby prohibited.

SEC. 2. The frequent emission of opaque smoke from the smoke-stack of any shifting locomotive engine, within the corporate limits of the City of Philadelphia, shall be deemed, and is hereby declared to be, a public nuisance, and is hereby prohibited.

SEC. 3. The discharge of opaque smoke for more than three minutes in any one hour, and repeated in subsequent hours, shall constitute frequent emission within the meaning of this ordinance.

SEC. 4. Any person or corporation being the owner, agent, lessee, trustee or manager of any boiler or shifting locomotive engine, and any person or persons employed in operating any such boiler or shifting locomotive engine, who shall cause or permit opaque smoke to be frequently emitted from the chimney of such boiler furnace or from the smoke-stack of such shifting locomotive engine, within the corporate limits of the City of Philadelphia, shall be guilty of creating a public nuisance, and shall, for such offense, on conviction thereof, be liable to a penalty of $10 for the first offense, $25 for the second offense, and $50 for each succeeding offense, to be recovered in the manner that penalties for breaches of city ordinances are now by law recoverable, unless the offender can satisfactorily demonstrate that the smoke emitted from the chimneys or stacks under his control is practically unavoidable and is determined by the necessities of his business which cannot be remedied.

SEC. 5. It shall be the duty of the Director of the Department of Public Safety, of his own motion or upon complaint in writing of any citizen, to enforce the provisions of this ordinance, and to make complaint and cause to be prosecuted all persons or corporations violating the same.

SEC. 6. This ordinance shall go into effect sixty days after its approval.

NOTES AND COMMENTS.

THE UNITED STATES REPAIR SHIP "VULCAN."

The following extract, from a recent report of Commodore G. W. Melville, Chief of Bureau of Steam Engineering, U. S. Navy, referring to the equipment of this unique craft and her service, will be of interest:

"In the last report, attention was called to the desirability of making such preparation for the fitting out of a vessel which would be a floating repair shop as would enable the work to be done with great rapidity when needed. Immediately, on prospect of war, the Bureau again brought this matter to the Department's attention, and the steamer 'Chatham' was bought, set aside for this purpose and named the 'Vulcan.' The work of installing the machine tools, cupola, forges, brass furnaces, etc., was pushed as rapidly as possible, as well as the selection of a force of skilled mechanics. A large and well-chosen outfit of stores of all kinds was also supplied.

"The 'Vulcan' arrived at Guantanamo on July 1st, and proved of the highest usefulness to the fleet, making repairs of all kinds and furnishing much needed supplies to every department of nearly every vessel. At the end of August reports from her officers showed that she had made repairs to sixty-three ships and had supplied stores to sixty. Her unusual facilities and the large number of skilled mechanics on board (about 100) enabled her to make repairs of all kinds, including hull work, gun mounts, dynamos, main steam pipes, main piston rods (for small ships), brass castings without end and iron castings in considerable quantity. This last is especially interesting as the first instance of the successful use of a cupola on shipboard."

At a special meeting of the Mechanical and Engineering Section of the Institute, Prof. Wm. S. Aldrich, late Assistant Engineer, U. S. N., who served on the "Vulcan" during her service with Admiral Sampson's fleet, gave a detailed description of the ship and her equipment, and narrated many instances, showing how indispensable an auxiliary vessel of this class must be in the naval operations of the future. W.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

A Teachers' Reception was given last week in the new Pierce Building on Trinity Place. Invitations were sent to the school Principals and Superintendents, Institute graduates teaching in Massachusetts and members of teachers' associations in Physics, Chemistry and Biology.

About eighty persons attended, including, among others, Dr. Tetlow, Mr. Collar and Mr. Parmenter, of the Boston schools; Superintendent Aldrich, of Newton; Superintendent Boyden, of Bridgewater Normal School; Superintendent Cogswell, Dr. Huling and Mr. Bradbury, of Cambridge; Mr. Whitcomb, of Somerville; Superintendent Gay, of Malden; Mr. Holt, of Arlington; Mr. Briggs, of Chelsea; Mr. Jackson, of Lynn; Mr. Lovering, of Winchester; Mr. Parker, of Brockton; Mr. Kelley, of Haverhill; Mr. Amen, of Exeter; Mr. Curtis, of the Hale School; Mr. Horne, of Dummer Academy; and Mr. Shaw, of Worcester Military Academy.. The Corporation was represented by the President, Dr. Williams, Mr. Wigglesworth, Mr. Wheeler, Mr. Lothrop, Mr. Gaffield and Mr. Munroe.

The guests were received by members of the Corporation and Faculty. Lunch was followed by an address by President Crafts. He discussed the relations between the secondary schools and the institute, and emphasized the privilege and duty of the secondary schools in discovering aptitudes in students, not merely directing students where chance, or parents' or teachers' preferences pointed.

Professor Chandler followed with a talk on the design and construction of school houses, showing by stereopticon slides and charts how the architects are endeavoring to meet the requirements of the educators.

Visits were then made by the guests to the various departments of the new building.

Mr. H. F. J. Porter, of the Bethlehem Iron Company, lectured to a large audience at the five hundred and twenty-first meeting of the Society of Arts last Thursday evening.

His subject was "Modern Forging," and he presented in a very interesting way, with numerous illustrations by the stereopticon, the methods in vogue at the Bethlehem Iron Works of forging such articles as hollow and solid shafts, dynamo field rings, guns, armor plate. Views were shown of the hollow shafts of the "Oregon," and of the "Brooklyn," made at these works. Defects in the old methods of forging and the steps leading to the present methods were well explained. W.

A NOVEL PUMPING ENGINE

The Holst pumping engine, devised by Mr. C. P. Holst, of Amsterdam, was designed, primarily to avoid the repeated stopping and starting of any part of the water, and thus to do away with the difficulties due to inertia.

The water flows in one direction only. In its passage from the inlet to the outlet it passes through four valves, which are attached to and move with the piston rods. At any instant three of these valves are open, allowing the water to pass through, while the fourth is closed, and, acting as a piston, takes all the work of pushing the water through the pump. This it continues to do for one-quarter of a revolution of the fly-wheel, when it becomes an open valve, and one of the others becomes a piston. W.

A NEW APPLICATION OF THE ROENTGEN RAYS.

The latest practical application of the Roentgen rays is to the testing of coal. It is stated that carbon in all its forms is quite transparent to these rays, while the substances—silica and the silicates—which constitute the ash or incombustible constituent, are opaque to them.

By placing a lump of coal between a Crookes tube and a fluorescent screen, it is stated that all the slag and clinker-forming portions of the fuel can be detected. M. Cuoriot, on whose authority this statement is made, has tested in this manner anthracite and bituminous coal, lignite, coke and artificially prepared briquettes. In these tests, rough lumps of coal, 1⅛ inches to 2 inches thick may be used, with an exposure of five minutes, and with a coil giving a 10-inch spark. W.

AN ELECTRICALLY HEATED FURNACE FOR POTTERY.

The London *Electrical Review* is authority for the statement that an English firm has developed an electric process for the production of ceramic wares which yields very superior results. Briefly described, it consists in the employment of photography for the production of the designs, and an electric furnace of special design for burning in the designs, the photographs being covered with a special glaze. The excellence of the product is stated to be due chiefly to the method of burning, the electric furnace permitting of being kept under complete control.

AN IMPROVED METHOD OF MAKING STEEL CASTINGS.

The merits of the Walrand-Legenisel steel process were made the subject of discussion at the last meeting of the American Institute of Mining Engineers. This process practically supplements the Bessemer process in such a way as to permit the making of castings directly from the converter. Its essential feature consists in the addition of ferro-silicon (containing from 10 to 12 per cent. of silicon) to the charge in the converter, when the flame drop takes place, and then making an after-blow. The oxidation of the silicon which takes place generates a large amount of heat, which is imparted to the metal—as the combustion product is not volatile—and the consequence is that the steel becomes strongly superheated. The metal is very fluid, produces castings quite free from blow-holes, and permits the making of intricate castings down to a fraction of a pound in weight.

By the usual methods in vogue, the production of sound castings, especially those of small size, has always been attended with great difficulties. The high degree of superheating attained in the new method appears to obviate this difficulty. The new process is successfully employed at large works in France and Germany, and in at least one large works in the United States.

W.

CAPITAL PUNISHMENT BY ELECTRICITY ADOPTED IN MASSACHUSETTS.

The State of Massachusetts will hereafter put its condemned criminals to death by the electric current, instead of by the hangman's noose. The Governor of that State lately signed a bill of the legislature making provision for the change. W.

USEFUL ALLOYS OF ALUMINUM.

With the considerable cheapening of the cost of aluminum, there has naturally followed a considerable extension of its applications in the arts. The physical properties of the pure metal, however, more especially its low tensile strength, and the difficulty of making soldered joints with it, have now come to be recognized as imposing considerable limitations to its usefulness.

But, although the pure metal has undesirable qualities, it is most fortunate for the future development of the aluminum industry, that it is capable of forming alloys that possess most valuable properties.

Thus, the alloy of copper with from 10 to 11 per cent. aluminum is one of the strongest known, its tensile strength ranging from 80,000 to 90,000 pounds per square inch. It also has a high elastic limit, but a low percentage of elongation (5 per cent. in 1 inch). The presence of silicon increases its strength and hardness, but decreases its ductility. Of the brasses the one containing 3·50 per cent. aluminum, 33·3 per cent. zinc, the rest being copper, is the best and strongest, having a tensile strength of from 75,000 to 85,000 pounds per square inch.

The addition to aluminum of a few per cent. of certain metals (such as nickel, tungsten or silver) likewise exerts a most beneficial influence in modifying the undesirable properties of the metal.

The production of such alloys, suited for a variety of special uses, has been the subject of extended investigation by the manufacturers of the metal, and they have been conspicuously successful. W.

MORE ABOUT "RUBBER FROM CORN."

The brief notices in the technical papers referring to the possibility of utilizing the refuse material of the glucose factories, amounting to about 5 per cent. of the raw material, have recently been supplemented by an interesting communication on the subject in the Chicago *Times*, purporting to give an account of experiments that have been secretly conducted in that city for the past year by the chemists of a large glucose company.

According to the writer of the article in question, the process of manufacture is now so far perfected that the product may, within a few months, be ready for the market.

The following details will be of interest:

"Corn rubber has almost exactly the appearance of the ordinary reddish brown india-rubber. The process of manufacturing is not perfect enough, however, to make it resist heat as well as india-rubber. This has offered the greatest difficulties to the chemists, who are now working to remedy this defect. The oil of corn, from which principally the rubber is made by some secret process, does not oxidize readily, and those who are working on the corn rubber declare this will be an enormous advantage for the new product. Articles manufactured from it will always remain pliable and not crack. Contrary to reports, this new product has not yet been put on the market. It is intended to go on with its experiments till the success of the new substance is assured, and then to go into its manufacture on an immense scale.

"The corn-oil from which the rubber is made, comes from the germ of the corn and not from the hull. The starchy and glutinous portions of the kernel are used in making glucose and starch, while the corn-oil, heretofore, according to the refiners, has been practically useless. The five refineries of the trust have used 21,000,000 bushels of corn in the last ten months, of which about 5 per cent. was refuse. Though forty different products are made by the company, still 5 per cent. was practically waste. By utilizing this waste material in making the new product it is calculated that corn rubber can be sold at 6 cents a pound, 2 cents of which will be clear profit. The corn rubber, it is said, will be adapted to nearly all the uses that ordinary rubber is capable of—from bicycle tires to linoleum. The more refined uses to which the rubber is put, however, will still be a closed field, for the composition of corn rubber will prevent its substitution for india-rubber for scientific uses."

The article proceeds to state that the new product may be advantageously mixed with Para rubber, producing a cheaper article of substantially the same quality for ordinary service, as the genuine rubber. W.

SEEING AT A DISTANCE BY ELECTRICITY.

Much interest has lately been aroused over the alleged discovery by Szczepanik, a Polish inventor, of a method by which vision at a distance is rendered practicable. The apparatus by which this is to be accomplished, is called the "Telectroscope." The complete details of this invention have thus far not been disclosed, but the *Scientific American* supplement has lately published an article giving the present state of knowledge on the subject of electrical vision, from which the following statements are taken :

As may have been anticipated, the fundamental principle involved in all the devices that have been proposed for this purpose is the variation in the electrical conductivity of selenium under the influence of light of varying intensity. To demonstrate this property of selenium, the simplest plan is to include a selenium cell in a telephone circuit, when a sharp click will occur in the receiver every time that a bright beam of light is allowed to fall upon the selenium.

Coming to the alleged discovery of the expert above named, it is said to consist in brief "in allowing the rays emanating from the object to fall upon a cell of selenium. Electric impulses will be produced in the selenium, whose intensity depends upon the brightness of the rays falling upon the cell. These impulses, being conducted to a distant receiving station, are there transformed again into light. The rays falling upon the selenium are first separated into points of light by oscillating mirrors in the transmitting station. Similar mirrors in the receiving station vibrate synchronously with the mirrors of the transmitting station, and reproduce the image of the object."

"The circumstance that the retina of the eye is sensitive to a light impression for a very minute, though definite, interval of time after the light has ceased to affect it, a peculiarity called by physicists the 'persistence of vision,' explains the fact that the rapid vibrations of the mirrors are perceived simultaneously.

"A spark on the end of a stick, when swung around in a circle, produces the impression of a ring of light. In an exactly similar manner, the rapidly succeeding points of light falling from the object upon the mirrors, produces, apparently, the image of the original object.

"The question then naturally arises : Is it possible to oscillate the mirrors with sufficient rapidity to produce a series of points, which, following one another with great rapidity, will cause a picture of the object to be produced?

"The mirrors are arranged in pairs at right angles, as regards their vibrations, and hence the number of points projected on the selenium in the transmitter will be equal to the product of the number of oscillations performed by each of them. If, for example, each mirror swings on its axis only 100 times a second, then 10,000 points of light will, in a like period, fall on the selenium and be transmitted. As a matter of fact, these may number hundreds of thousands, or even millions. So rapid are the oscillations of the mirrors that the tenth part of a second is sufficient to analyze the image of an object in the transmitter, and to render it visible at the receiving station. It is therefore, possible to transmit a continuous action, such as a theatre performance, over the wires of the telectroscope, since the pictures received follow one another so rapidly as to produce the impression of a moving image, just as the numerous separate pictures of a chromo photographic apparatus reproduce past actions."

It is stated in the article from which the foregoing account has been abstracted, that it is the inventor's intention to withhold full details of his system and apparatus until the same shall be shown in operation at the World's Fair in Paris to be held in 1900.

Apropos to this, it is worthy of notice that this inventor has made the same reservation about disclosing the details of another alleged invention, no less remarkable in character than this one, and which also was recently the theme of much discussion in the technical and newspaper press. It would be quite as well, under these peculiar circumstances for the public to await these promised revelations and meantime to do as the gentleman with the unpronounceable name has done, accept his statements with reservation. All that can safely be said of this particular invention is that it is possible in theory, and plausible so far as the details have been disclosed. W.

NEW USES FOR ALUMINUM.

It is reported that experiments have been carried on at the United States Mint in Philadelphia for nearly a year with the view of ascertaining the fitness of aluminum for minor coins. Some 10,000 blanks of the size of the nickel (5-cent piece) have been delivered at the mint for this purpose. It may be mentioned that Congress some time ago appointed a commission of experts to investigate and report upon this subject, and the experiments above referred to are being carried on under the direction of its members.

In the source from which the foregoing information is taken, no allusion is made to whether the blanks are of pure aluminum or of aluminum alloyed with a hardening metal. The pure metal would in all likelihood prove objectionable in service as a coin metal.

A current item of news relates to the interesting fact that one of the great electric companies, which is engaged in the equipment of a large electric power transmission plant in the State of Washington, has ordered 200,000 pounds of ¼-inch aluminum wire for carrying the current. This is practically a new field for the aluminum industry, and promises a great expansion in the near future. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, February 15, 1899.*]

Hall of the Franklin Institute,
Philadelphia, February 15, 1899.

Mr. Theo. D. Rand, Vice-President, in the chair.

Present, 92 members and visitors.

Additions to membership since last month, 64.

The report of the Actuary embraced the following important information :

"* * * Upon the recommendation of the Committee on Sectional Arrangements, the Board of Managers has authorized the formation of a 'Physical and Astronomical Section,' of the Institute, upon the petition of the following-named members, whose names have, in accordance with the By-Laws, been recorded as the founders of the Section ; to wit :

"Prof. E. J. Houston, Philadelphia, Pa.

"Prof. Geo. A. Hoadley, Swarthmore, Pa.

"Prof. E. A. Partridge, Central Manual Training School, Philadelphia.

"Prof. A. S. Mackenzie, Bryn Mawr College, Bryn Mawr, Pa.

"Prof. Geo. F. Stradling, Northeast Manual Training School, Philadelphia.

"Dr. A. E. Kennelly, Crozer Building, Philadelphia.

"Prof. Luigi d'Auria, 3810 Locust Street, Philadelphia.

"Prof. Thos. E. McDermott, Catholic High School, Philadelphia.

"Prof. Eugene C. Foster, Temple College, Philadelphia.

"Prof. Jesse Pawling, Jr., Central High School, Philadelphia.

"Prof. Harvey Newcomer, 4116 Spruce Street, Philadelphia.

"Prof. Richard Zeckwer, Philadelphia Musical Academy, Philadelphia.

"Prof. G. B. M. Zerr, Central High School, Chester, Pa.

"Prof. Eric Doolittle, University of Pennsylvania, Philadelphia.

"Prof. J. M. Moyer, Northeast Manual Training School, Philadelphia.

"Prof. L. T. Edwards, Haverford, Pa.

"Prof. Geo. H. Hallett, University of Pennsylvania, Philadelphia.

"Mr. Paul R. Heyl, Reading, Pa.

"In addition, I am directed by the Board, to report the following resolutions, adopted at its stated meeting, held Wednesday, February 8th, 1899.

> "'*Resolved*, That the Board of Managers requests the Franklin Institute to pass the following resolution :
>
> "'*Resolved*, That the Franklin Institute, for the promotion of the mechanic arts, hereby authorizes the President and Secretary of the said Institute to make, sign, seal, execute and deliver unto the Trustees of the said Institute, a deed for the real estate, No. 1543 Page Street, in the city of Philadelphia, devised to the said Institute by the will of M. Carey Lea'

"I have to report further, that the Board being informed of the introduction of a bill into the Legislature of the Commonwealth at Harrisburg, making an appropriation of $200,009 to the Trustees of the Philadelphia Museums, to assist in the 'National Exposition for the Encouragement of the Export Trade,' which is to be held the coming fall under the joint auspices of the Philadelphia Commercial Museums and the Franklin Institute, the Board adopted the following resolution :

> "'*Resolved*, That the Committee on Exhibitions be hereby authorized to frame a resolution on behalf of this Board, urging the adoption by the Legislature of the Commonwealth of Pennsylvania, of the Act, making the appropriation of $200,000 above referred to, and present the same to the meeting of the Franklin Institute, with the recommendation of the Board that it be adopted.'

"The Committee on Exhibitions, in accordance with the Board's instructions, has framed the attached preamble and resolution, which is herewith offered for adoption upon the Board's recommendation, as above stated :

> "'To the Honorable Senate and House of Representatives of the Commonwealth of Pennsylvania, assembled at Harrisburg, greeting.
>
> "'WHEREAS, A bill has been introduced before your Honorable bodies, entitled "An Act Making an Appropriation to the Trustees of the Philadelphia Museums to assist in the National Exposition for the

Encouragement of Export Trade," and asking for an appropriation of the sum of two hundred thousand dollars, therefor; and,

"'Whereas, The Franklin Institute of the State of Pennsylvania is associated with the Philadelphia Museums in holding the said National Exposition jointly, the Franklin Institute at its stated meeting held February 15, 1899, adopted, by a unanimous vote, the following resolution:

"'*Resolved*, That the Franklin Institute hereby extends its approval to the aforesaid bill, and urges its prompt and favorable consideration by the members of the Senate and House of Representatives of the Commonwealth of Pennsylvania.'"

Prof. F. L. Garrison, on behalf of the Committee on Exhibitions, gave a summarized statement of the progress made in arranging the preliminaries for the forthcoming exhibition.

Prof. Arthur J. Rowland, Drexel Institute, Philadelphia, made a brief communication on "The Photometry of Incandescent Lamps," describing a special plan of using a photometer for directly determining their candle-power. He illustrated his remarks by a portable photometer, made by the Newark Ornamental Sign and Iron Works, of Newark, N. J. This is a Bunsen photometer, or one in which a measurement of candle-power is effected by moving a paper with a grease spot on it, backward and forward along a line joining two lights to be compared, until the grease spot disappears. The candle-power of one light being known, a measurement of distance to the paper from each of the lights, gives the necessary data for computing the candle-power of the other one.

The features of the photometer shown, were a scale reading directly in candle-power, an incandescent electric lamp is a known standard, and an oil lamp as a sort of secondary or intermediate standard.

In operating the device, the incandescent standard is set up in position where the lamps whose candle-power is to be determined are afterward put, and the flame of the oil lamp adjusted to known candle-power at the other end of the photometer bar. The standard is then removed and other lamps of unknown candle-power substituted and measured. By using the oil lamp in this fashion, nearly all the common difficult and tedious processes of photometry are avoided, only one voltmeter is required, and only one adjustment of the electromotive force given the lamp.

Professor Rowland explained how, from his own experience with the instrument, an accuracy of determination of candle-power to within $\frac{2}{10}$ of a candle-power in 16 is readily attained in a room not especially darkened for the purpose. That is, a single determination will not be more than $\frac{2}{10}$ of a candle-power above or below the true value. This is quite good for a commercial photometer.

The subject was referred to the Committee on Science and the Arts for investigation and report.

Mr. Louis Edward Levy described and exhibited in operation the "Acid-Blast Process for the Etching of Photo-Chemical Engravings," a process and apparatus of his invention.

It consists essentially in the application of a spray of finely atomized etching liquid instead of the immersion bath at present in use, the spray being driven against the plate by a powerful blast of air from an air compressor. The air is forced through a large number of aspirators which are fixed at the bottom of a shallow tank containing the etching liquid and enclosed in a case to confine the acid vapor. The inlets of the aspirators are submerged in the etching liquid, while the outlets protrude above its level, and these are so arranged that a homogeneous cloud of acid vapor is forced by the air blast against the plate at a right angle to the surface. The plate is fixed on a carrier which slides into a movable frame within the etching box, and is held in a horizontal position with its face downward over the aspirators. The movable frame is connected with an eccentric carried by the driving shaft of the air compressor, and the plate thus receives a slight reciprocal motion in a horizontal plane. This gives a rocking motion to the drops which form in hanging globules on the inverted face of the plate, and which, being held against the plate by the air current, are naturally largest in the wider and deeper depressions of the etching. As the fresh acid particles composing the spray are driven by the blast to the back of these hanging drops and into contact with the metal, the surplus of the drops, carrying the spent acid, falls back into the receptacle below.

Under the impulse of the blast the etching proceeds very rapidly. The heat evolved by the rapid chemical decomposition of the metal is absorbed by the expansion of the compressed air as it escapes into the etching compartment, and this results in keeping down the temperature of the plate and the etching liquid to a normal degree. The fumes developed in the chemical process are carried out of the etching case with the escaping air current through a ventilating pipe to the outer air.

As explained by Mr. Levy, the normal degree of chemical affinity in the minute globules of acid carried by the blast is enhanced by the force of their impact on the metal with which they are intended to combine. This results in each globule of acid becoming saturated with the metallic base instantly on contact with the latter, thus losing its power of further dissolving the metal, and consequently the possibility of etching sideways under the reliefs of the design. As each succeeding globule of acid impinges on the metal in the direction in which the etching is required to proceed, the process can be continued to a depth beyond which the finer and closer lines of the design would become too frail to bear the strain of printing, and at that point the etching is stopped and the finer lines are protected by powdering in the usual way, after which the etching can be carried to the requisite depth.

Attached to the etching box is a washing compartment, into which the plate carrier is slid when the etching liquid is to be washed away from the plate. By an arrangement of three-way cocks connected by a lever, these cocks are opened to permit the air current to drive water from a reservoir up against the face of the plate through perforated pipes at the bottom of the washing compartment.

The blast process as exhibited before the Institute affords a considerable saving of time as compared with the old method, which was also demonstrated by Mr. Levy, and has furthermore the advantage of protecting the etcher against the deleterious effects of the acid fumes.

The paper and demonstration called forth considerable discussion. The subject was referred to the Committee on Science and the Arts.

The Secretary presented a brief report, and the meeting adjourned.

WM. H. WAHL, *Secretary.*

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Mining and Metallurgical Section.

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BUILDING-STONES—ELEMENTS OF STRENGTH IN THEIR CONSTITUTION AND STRUCTURE.*

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The imperfect and insufficient methods hitherto in vogue, for determination of value of stones for purposes of construction, have produced a general dissatisfaction and consequent neglect which are to some extent reasonable and within excuse. They are unsatisfactory because mostly antique, devised at a time when little was known of the internal nature of the material to which they were applied, when an exaggerated view was prevalent in regard to the homogeneity of stone, at least in each locality, and when little effort

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*Abstract published in *Stone*, 1898, and elsewhere. Reference has been made in the notes to the more important statements which have appeared in the literature of the subject, during the year since the reading of this paper, concerning points discussed herein.

was or could be made toward correlation of observations and tests applied to its different properties. The classic monograph of Q. A. Gillmore,* which still remains the basis of certain methods and data accepted throughout the literature of this subject, affords abundant and unfortunate examples of imperfections and errors. A large amount of similar work has since been done throughout the country whose results, if published, would be for the most part of as limited value, from absence of exact study and descriptions of the specimens, for identification, and of other comparative tests. This scantiness of data and consequent inefficiency of result marked the exhaustion of knowledge of the characteristics of stone at the early period of its investigation—a period, however, which was distinguished for much anxious care as to proper choice and use of stone in construction. The rich sources of information on this subject, now supplied by petrographical research, suggest the need of a general review and complete revision of all these methods, for correction of our present store of data from the new standpoint, by all interested in the investigation of this important structural material.

The present neglect of known methods of trial, with the slight progress yet made toward their improvement, results too often in the haphazard selection and use of stone, rather from views of convenience, assumed experience, economy, beauty of color-scheme and adaptability to decoration, than from regard to strength and durability; in fact, often with apparent indifference whether the food for the stonecutter's chisel shall turn out, under the tests of continuous pressure and of weathering, to be "fish, flesh, fowl or good red herring." One builder contents himself with a test or two on the compressive strength of a sample of new stone; another may call for a complete chemical analysis of the sample in question, and thereby his judgment is lulled to rest; another satisfies himself with conclusions from observations on venerable buildings erected within a period of ten or twenty years past (what more can an American want!), or even with a similar stone for a longer time, though often under entirely different conditions and climate, in any old country, such as Italy, Greece or Spain. The engineer is inclined to put chief or entire reliance on experimental trials of the resistance of stone to stress, applied in various ways; the chemist on determination of its ultimate composition. The physicist supplies a series of interesting tests of important properties, specific gravity, absorption-power, resistance to oxidation, etc. A geological expert is apt to rest his conclusions mainly on study of natural exposures in vicinity of the quarry. General experience, however, testifies to the mistake of neglecting that thorough preliminary examination of a building-stone, at least for important constructions, which may involve all these and other well-known processes, though they may require weeks or months of competent and exhaustive investigation. Considerations of assumed economy, particularly when a contract has been limited in time, or where stones from several quarries would be required, have usually led the constructor to dispense with these. The deplorable results have been familiar to all in masonry fractured and crumbling before its own completion, as observed during erection of the State Capitol at Albany, N. Y., the State House at Hartford, Conn., the Philadelphia City Hall, etc.

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* Report on Building-Stones (1876), tables, pp. 32-37.

The extent and difficulty of the needed investigation result from the complexity of materials, forms and structures comprised in a stone. At a glance at the magnified picture* of its internal constitution (such as that shown in *Fig. 1*), the thought arises: "What complicate variety, what lawless disorder! Little wonder that a half dozen sciences—mineralogy, petrography, geology, physics, mechanics, engineering—must be summoned to our aid!" But the architect or engineer can be as rarely conversant with the mineralogical constitution and petrographical structure of the material he so freely handles, as the geological or chemical expert with the variety of excellent experimental tests which have been designed for its exploration. It is into this borderland of apparent crystal chaos that you are invited to enter, to consider, from the point of view of modern petrography, the elementary conditions on which the strength and value of building-stone depend. Until these shall have been thoroughly worked out, understood and applied, there can be little harmony or satisfaction in methods proposed for artificial investigation and trial, in modes of treatment of this material in construction and in safe processes for its artificial preservation. Such an inquiry, too, may suggest new lines of research, yet to be devised, for the purpose of clearing up vague or conflicting conceptions of the characteristics of stone.

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* All photo-micrographs in this paper represent a magnifying power of 40 diameters.

Theoretically, its strength, as dependent upon the tenacious coherence of its particles, might be taken to imply identical resistance to every disintegrating force; whether to one of compression and fracture under load; to the tearing asunder of grains by shearing pressure during partial support of a block at but one end or at both; to pulling apart during longitudinal tension or bending; to prying away of its minerals by frost-films in their interstices; to explosion by steam within its pores, or to violent alternations of expansion and contraction during exposure to sun, to fire or to sudden chilling of heated surfaces by cold water; to the loosening effect of acid rainfalls and of all the physical and chemical agencies concerned in the process of discoloration, softening, disintegration and exfoliation by weathering.

Practically, the compressive strength of a stone, though it may reach many thousands of pounds to the square inch, may be found to bear no relationship, yet recognized, to qualities concerned in durability. An approach to coincidence in the two properties prevails, to any material extent, only in a few of the building-stones, the granites and the finer fragmental, *e. g.*, in a fine-grained sandstone of great compressive resistance, such as the brownstone of Belleville, N. J. (*Fig. 1*), with 11,000 pounds to the square inch.

Practically, also, the resistance of a stone to atmospheric attack is largely modified by climate. So that, for instance, if we should represent the comparative durability of a series of freestones of known compressive strength, in the climates of our own continent, by graphic curves in which the abscissæ should indicate degrees of north latitude, and the vertical ordinates, percentages in a scale of comparative durability, these curves, all starting from maximum of durability at the equator, would fall slowly to about north latitude 35°, then rapidly and far between latitudes 35° and 55°, returning sharply toward the maximum throughout the arctic area. The depth of fall of each curve below that maximum, for stones of fragmental constitution, would be to some extent inversely proportional to their degrees of compressive strength. In other words, in the uniform conditions of temperature and climate which prevail in the torrid zone, and to a degree in the arctic, freestones of little or of great compressive strength are almost equally durable, and such strength needs consideration merely in reference to loads involved in construction. Within the tract of the northern temperate zone, however, the structural weakness of any freestone usually corresponds to lack of resistance to weathering agencies, to fire and to wear by attrition. With stones of crystalline character, such as marbles, dolomites and granites, no such parallelism would usually occur between the curves of structural strength and of durability. With these, far more complex conditions call for consideration, and other methods of experimental trial must be employed. Different principles apply to the stones of each class; each must have, to great extent, its own rules and its own tests. Much of the confusion in our present literature is due to the useless attempt to combine, and thus apparently to simplify, discordant conditions and conclusions.

In considering, then, the actual elements of strength, we encounter at the outset and must accept, I think, the apparent paradox that, so far as shown by investigations yet made, the strength of a stone has little to do with that of its constituent minerals. So far as we yet know, it matters little whether these consist of brittle quartz, with its compact texture (hardness, 7), or of varieties of tough feldspar, with some tendency to rift (hardness, 6 to 7), of fibrous hornblende or tenacious augite (hardness, 5 to 6), or of calcite or dolomite, with easy cleavage (hardness, only 2·5 to 4).

In occasional rocks, of course, some prominent property seems to be plainly connected with that of a predominant mineral-constituent, *e. g.*, the toughness of traps and many schists with that of the contained augite or hornblende, the resistance of dolomitic limestones to the probable strength of the mineral dolomite,* etc.

No determinations are yet on record, I believe, of compressive strength, resistance to weathering, to fire, etc., of the common individual minerals which make up building-stones. In their absence, how can we safely generalize concerning the irregular aggregates of minerals which we find in every rock we use? It may be anticipated that the results of such determinations on minerals will be found to vary with relation to crystallographic axes, like other physical properties already determined by the mineralogist and physicist, viz.: cleavability, hardness, tendency to solution, temperature expansion-coefficient, etc. So here, in the very beginning, is a considerable hiatus in our knowledge; we study the aggregate, the stone, in considerable ignorance of the nature of its constituents, the minerals; these yet remain to us unknown hieroglyphics of the ancient manuscript we are trying to decipher. On the one hand, we may admit the possibility that the variations of minerals, in reference to such properties, may be so limited, that they shall be ultimately found of minor importance, compared with variations in conditions of arrangement and in mutual relationship of intermixed grains. On the other, is it but a wild fancy to conceive, in reliance on the definite laws of force, that, with the pertinent physical data once established for each constituent mineral, it may yet be possible to calculate, from the grains exhibited in a few thin sections of a crystalline stone (such as the hornblendic granite of St. Cloud, Minn., *Fig. 2*), an estimate of its crushing resistance, etc., at least as approximately correct as the results now commonly deter-

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*J. H. L. Vogt, "Der Marmor in Bezug auf seine Geologie, Structur und seine mechanischen Eigenschaften."—*Zeits. f. prakt. Geol.* (1898), 16.

mined for a whole quarry or group of quarries by experiments on a few cubes cut from the same block!

Objection has been often advanced to further determinations of this property, on the grounds both of the imperfections of the method and the widely discordant variations of the results thereby obtained, and also of its uselessness, since the estimated figures for crushing strength enormously exceed the actual stresses endured by stone in masonry.

As to its imperfections, these have been clearly due, in part, to vague identification of the varieties of stone under examination. For example, in Gillmore's tables, we find the term "blue granite, Staten Island, N. Y.," applied to the diabase of that locality; "Harlem stone, Morrisania, N. Y.," to indicate some kind of gneiss; the terms "dark," "light," "gray," "rose," etc., as sufficiently descriptive, in connection with the noted specific gravity, for identification of the tested varieties of stone, etc. In fact, the hasty presumption of the local homogeneity of stone has since led to common use of regional terms, such as "Maine granite," "Vermont marble," "Indiana limestone," etc., in connection with definite physical data obtained from a few specimens of limited occurrence.

Again, we find extreme variations in figures for compressive strength attributed to supposedly definite varieties: such as, "light granite, East Bluehill, Me., 12,125 to 16,250," "syenite, Cape Ann, Mass., 12,861 to 19,280," "gray granite, Peterhead, Scotland, 8,290 to 18,636," "marble, Pittsford, Vt., 11,250 to 18,750," "bluish marble, Lee, Mass., 7,705 to 17,954," "brownstone, Portland, Conn., 5,806 to 10,928," etc.

In fact, a single statement by Gillmore, "each specimen of all the kinds was carefully prepared by an expert stonecutter, and the bedside marked"—throws doubt on the accuracy of all his experimental figures, on account of the well-known weakening effect produced on stone surfaces either cut or "stunned" by blows, and the consequent inferiority of hewn to sawn cubes.* However, there is no present need nor probability of the repetition of such errors, and we may confidently expect that the variation in figures will be minimized, in the more thorough investigations of the future, by careful and exact selection and identification of varieties of stone for trial, by improvement in the apparatus and methods of test and by uniformity in the mode of their application. The need of accurate estimation of this property in stone has been shown by repeated instances of its fracture under load in masonry, which are likely to increase with the modern tendency to erection of lofty buildings.

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*T. H. Johnson obtained for the crushing strength of oolite-limestones of Indiana, when tool-dressed, 7,857 pounds; when sawn, 12,675 pounds.—Rep. State Geol. Ind., 1881, p. 45.

Again, it will become better understood that resistance to crushing and resistance to all other forms of disruption of grains in stone are equally functions of their intensity of coherence. We may therefore also hope for future researches which shall reveal the approximate relationship of all these factors, and shall supply us, for each kind of stone, with certain coefficients, as yet unknown, of resistance to disintegration by shearing, by freezing, by abrasion, etc., which may be applied to its accurately determined figure for crushing strength.

But there seems to be an additional reason not only for the continuance of this method of investigation, but for its most thorough prosecution in the future, subject to an important and hitherto neglected modification. It has been shown by Professor Hoskins* that, under a predominant pressure in one direction, a rock which is rapidly deformed may pass beyond its elastic limit and become ruptured; but when under less rapid deformation, it may simply tend to flow. Under great stresses in artificial constructions, similar conditions might be presupposed, although entirely ignored by architect and engineer. In fact, abundant evidences of permanent flexure and deformation have been observed in apparently unimportant constructions (elsewhere referred to), such as the sagging of stone beams and slabs after long suspension with partial support, and the flexure of hewn blocks

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* L. M. Hoskins, "On Flow and Fracture of Rocks as Related to Structure," U. S. Geol. Survey, Sixteenth Ann. Rep. (1894-95), 847.

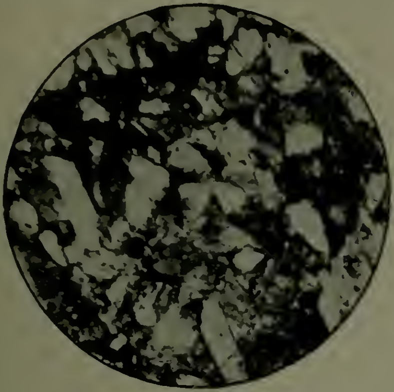

Fig. 1.—Sandstone.—Belleville, N. J.

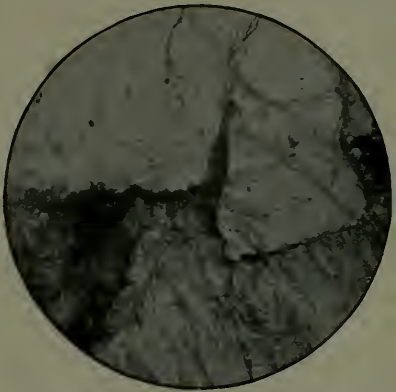

Fig. 2.—Hornblendic Granite.—St. Cloud, Minn,

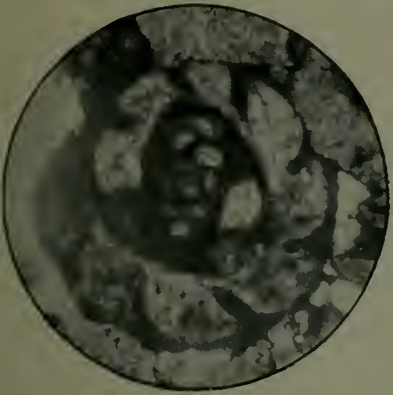

Fig. 3.—Foraminiferal Limestone. Hinesville, Ind.

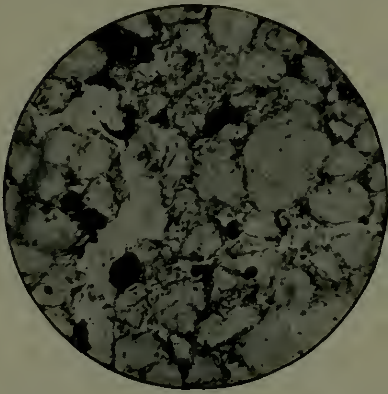

Fig 4—Quartz-Sandrock.—New Lisbon, Wis.

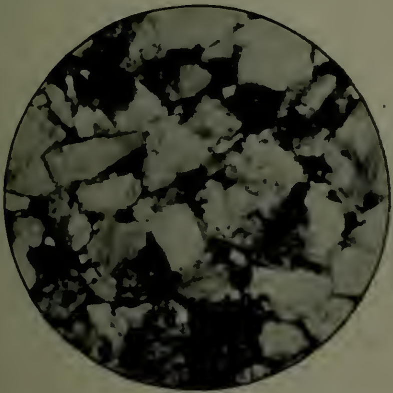

Fig. 5.—Sandstone.—Dorchester, N. B.

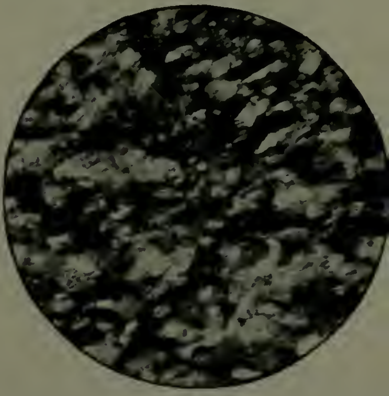

Fig. 6.—Sandstone (Bluestone).—Meshoppen, P

Plate A.

of marble in quarry-yards and of stone wainscot and mantels in ancient buildings. As Van Hise observes, "This latter case shows how important the element of time is in the deformation of rocks, and that, given a sufficient time, a stress much below the ultimate strength may surpass the elastic limit and result in flowage."*

It is still to be determined whether, under pressures actually existing in the walls of lofty and massive edifices, a tendency to plasticity, yielding and flowage, rather than fracture, may not have often become developed in a hewn block of building-stone, even partially enclosed within masonry on five out of its six sides, given sufficient time. No measurements seem to have been taken on the lower blocks in lofty monuments, especially when ancient, to distinguish traces of deformation, though it may be safely presumed that such results of plasticity must have sometimes occurred.

Evidently, then, the usual method of determination of crushing resistance in stone cubes, as laid down by Gillmore, and ever since faithfully followed, has been vitiated by a serious source of error, the neglect of the element of time. On this Gillmore had only this to say, "The power applied neither fast nor slow, but steadily."†

But the experimental conditions of pressure rapidly applied beyond the elastic limit within a brief period, usually of a few minutes, differ widely from those borne by hewn stone in construction, the gradual, slow and indefinitely continued application of load. A method of experimentation is called for, founded on the gradual and slow increment of pressure during a long period, up to days, weeks or months. Gillmore's work can then be but the basis and beginning of a long called for revision of our present methods. In this conclusion I have been confirmed by the results of experiments carried on in 1886, upon a homogeneous dolomite from Western Massachusetts, and which may hereafter be published.

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* C. R. Van Hise, "Principles of North American Pre-Cambrian Geology," *idem*, 594.

† Report, p. 6.

It is certainly beyond question that the blocks of hewn stone, as received by the builder, are always seamed and weakened by very minute cracks, partly superficial and partly internal, of unknown number and dimensions, often referred to as "flaws" or "checks." These are in part natural, originating in the tensions and stresses to which the rock-strata have been subjected. Others are artificial, in large part unnecessary and avoidable, having been produced during rude processes of quarrying; by the use of heavy blasting, in place of light charges properly distributed, or in a lewis-hole; by the continued application of heavy hammers, instead of channeling machines, for loosening blocks of rock;[*] by the rough handling and dumping of loosened masses, and even their hurling down mountain sides to facilitate transportation—the abuse to which Carrara marble is subjected; by the exposure of freshly quarried blocks to freezing temperature, with consequent flaking, fracture and development of internal rifts; and by rough hewing and dressing, the surfaces being "stunned" by heavy implements during ax- and bush-hammering.[†] It is this peculiar class of defects in stone which calls for special trial in compression tests, and it is readily conceivable that a cube of stone, capable of resistance to enormous pressure, many thousands of pounds, rapidly applied, might be fractured or even crushed, through gradual opening of its clefts, under a continuous load of a few hundred pounds.[‡]

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[*] T. C. Hopkins, "The Building Materials of Pennsylvania; I, Brownstones" (1896), 24–25.

[†] G. P. Merrill, "Stones for Building and Decoration" (1891), 397.

[‡] The following conclusions, in a recent discussion of the testing of marbles, are equally applicable to other stones:

"We would expressly point out that the resistance of marble to crushing has nothing to do with the hardness of the stone. It is also not directly proportional to texture and to durability in the open air; for example, even a tolerably loosely grained dolomite-marble possesses a very considerable compressive resistance. This cannot, therefore, depend directly upon compactness of texture; the tests with cubes, of 5 to 8 centimeters on a side, are not generally of such decided value as at first thought. With excessively great overloading, marble is not usually crushed through destruction of its grain, but this results in consequence of sundry fissures and clefts, often indistinguishable by the eye; and this is not recognized by tests on cubes."—Vogt, *loc. cit.*, 44.

However, with this exception, it is not the purpose of this paper to discuss the methods of trial or test of the strength of stone, but rather the foundations on which such methods ought to rest, *i. e.*, the question, What are the chief elements of its strength? These are characteristics of fragmental or of crystalline granulation and may be comprised in four classes, represented by the terms, *interlockment*, *coherence*, *tension* or *strain*, and *rigidity*.

I. INTERLOCKMENT.

Three stages may be distinguished in the initial arrangement and progressive consolidation of mineral grains within a building-stone.

(1) *Irregular Aggregation*, in which grains of a fragmental stone occur simply heaped together in a helter-skelter mass, like jackstraws. An extreme case is found in "beach sandrock," the barely cemented agglomerates of calcareous sands on many marine beaches of the Gulf of Mexico, Caribbean Sea, Southern Atlantic, etc., *e. g.*, the so-called "marine conglomerate" of the Old Government Quarry, near Hamilton, Bermuda; also, in beds of earlier age, certain varieties, cellular and partially cemented, of oolitic and foraminiferal limestones of our Western States, such as that of Hinesville, Ind. (*Fig. 3*). In these we find fossils, grains or pebbles so irregularly disposed that each lies in mere contact with its neighbor, touching at but few points, with numerous unfilled, intervening cavities, and largely unsupported; there is generally little evidence of sorting or rearrangement by wind, water, superincumbent pressure, or motion of the mass. Other examples are offered in the ferruginous sandrock of our Atlantic Coast, sometimes used for building in Ocean and Monmouth Counties, N. J.; in some brownstones of the Trias deposits of New Jersey and Connecticut; in the friable sandrocks of the Northwest, with their rounded, poorly cemented grains, *e.g*, that of New Lisbon, Wisconsin (*Fig. 4*), and, among crystalline stones, in some porous dolomites of Minnesota and volcanic tufas of the Western States.

In consequence of this irregular disposal of grains, stones of this class are likely to enclose a vast abundance of small and large cavities, resulting in porous cellular texture, inferiority of compactness and weight, low compressive resistance, and enormous absorption-coefficient; all these conditions tend toward weak qualities in a building-stone. In a porous marble, limestone or cellular sandstone with calcareous cement, the cavities may afford, in a moist climate, a *nidus* for vegetable growths and consequent deep decay of the stone during weathering. Yet the loose texture may be offset in the direction of both compressive strength and resistance to weathering, by presence of strong cement, lining the cavities in the form of calcite, quartz or crystalline variety of iron-oxide: and even a porous dolomite or volcanic tufa may possess great durability, by virtue of its very insolubility. The enclosed air-cavities also favor more general uniformity of temperature through the stone, and, in a building thereof constructed, desirable protection from external variations in the climate, though often with undesirable tendency to dampness within.

(2) *Parallel Sorting.*—In fragmental stones, this position of grains sometimes results simply from their platy form, such as the shell-fragments in "coquina limestone," of St. Augustine, Flor. It may be also derived from partial sorting and rearrangement by wind, as in the calcareous sandstone of the quarries of Bermuda, known to be entirely an aggregate of shell- and coral-fragments, heaped up by gales on that ancient reef and afterwards consolidated by percolating rainwaters. Elsewhere it may be the consequence of sorting of sand-grains during deposit under water, accompanied by gradual increase of superincumbent load, forcing the larger grains to assume the position of greatest stability, *i. e.*, horizontality, and the smaller particles to ooze and pack into the adjoining cavities, *e. g.*, in the freestone of Dorchester, New Brunswick (*Fig. 5*).

In the crystalline stones, whose grains have emerged from a stage of plasticity or fusion, a similar parallel disposal has been commonly produced by intense pressure, by flow of the viscid plastic or fused material, and by a shearing movement, the tangential resultant of force which has accompanied subterranean shiftings of the earth's crust; this is often represented in the gneiss-structure (*Fig. 7*).

The final and most complete interlockment of grains is offered in the form of

(3) *Dovetailing* or *interpenetration.*—Here those minerals, whose grains in a fragmental stone, or whose imperfect crystals, in a crystalline variety, possess the elongated form of bars, plates or prisms, have been settled down into parallel position in the bedding-plane of the original rock, or subsequently into its schist-plane, and act as a binding-material, like the hair-fibers in mortar, the straw or dung in a sun-dried brick or adobe, or the cross-bonds in masonry. These are well exhibited in the "Wyoming bluestone" of Meshoppen, Pa. (*Fig. 6*). While these plates are thus indeed presented in the readiest position for cross-fracture by pressure from above, this is more than counteracted for themselves by the completeness of their enclosure and mutual support. Within the mass itself they must exert the most powerful resistance to tearing apart of grains by longitudinal tension, through expansion by frost-films, by fire and by absorption of moisture. The extent of their influence, as elements of strength, must be proportional to their number and heightened by the associated obliteration of cavities and consolidation. They are most clearly distinguished in a thin cross-section of the stone. However, a stone in which they abound may possess but one position of stability, that of the bedding-plane. Placed on edge, the general parallelism of its grains may become a source of weakness, through the tendency to ready cleavage so imparted. Thus, in particular, the parallelism of mica-scales, which might exert a strong binding action in horizontal position, becomes a principal cause of the well-known destruction of blocks of micaceous sandstone by weathering, when erected on edge in ashlar.

These features are still more prominently displayed in the close interlockment of crystals in crystalline stones, the marbles, dolomites, traps, granites and gneisses. In these loose aggregates may indeed occur, *e. g.*, in the dolomites, composed of polygonal grains with nearly smooth and often slightly curved faces, feebly pressed together and easily separated; or, at the other extreme, in the calcite-marbles and many granites, grains with irregular or even zigzagged outlines, roughened faces and projecting tongues, moulded upon and forced into each other, in the most intricate and inseparable form of interlockment.* The degree and effect of this mutual interpenetration may be appreciated by a study of the dovetailed masses of quartz common in most granites (*Figs. 2* and *15*). In other stones, the minerals alternate in smooth plates and lenses—it may be, of quartz, feldspars and micas—mutually intercalated and overlapping, as in the common gneiss of Philadelphia and New York (*Fig. 7*). In many, films and strings of mica are intermixed, to bind the mass still more closely, or even fibers of tough hornblende and augite lend their tenacity to the strength of the stone.†

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* "In our best American marbles the edges of the crystals are clean and firm, and are often knit together like the bones of a skull."—G. W. Perry, "The Relation of the Strength of Marble to its Structure," *Eng. and Min. Jour.*, (1891), 453.

† The views of Vogt, concerning the relations of texture and strength in the marbles of Europe may be summarized as follows: Contact-metamorphic marbles (those developed in vicinity of trap-dikes) are generally loosely granular, partly because their calcite-grains, like the grains in dolomite-marbles, are not closely compacted and interlocked, and partly because the angles and edges of the other enclosed minerals (garnet, augite, etc.) are often rounded. For this reason many quarries have been given up and only a few yield solid marble. In regional metamorphic calcite-marbles (corresponding, for example, to those of Vermont, Pennsylvania and Tennessee) the solidity is mainly caused by the intricate interlockment of the calcite-grains and increased by the presence of quartz, and also by the pegmatitic texture (like that of graphic granite), where the large calcite grains are sprinkled with many enclosed granules of the same mineral. On the other hand, a "cataclastic" character, a brecciated condition produced by crushing during dynamic metamorphism, in which both cleavage-faces and gliding-planes show curvature, indicates fragility and uselessness of the stone; a saccharoidal constitution is also somewhat unfavorable. In regional metamorphic dolomite-marbles (corresponding to those of Southern New York and Western Massachusetts), many varieties are loosely granular and worthless, the finer being even sandy to great depth; while some whose grains are less curved in contour improve below the depth of 5 meters, and become suitable for sculpture, and even for building. In most of them, however, the grains are poorly interlocked, so that the marbles are of feeble texture and inferior quality.

We must also note that, from causes never yet clearly explained, strange exceptions occur to the prevalent rule of excess of compressive strength of a stone "on bed;" a considerably increased strength "on edge" has been observed by Gillmore and others in many samples of granite, hornblendic granite, dolomite, limestone and sandstone. The source of such anomalies might have been revealed, by study of the texture of the stone, in some mode of interlockment, perhaps in the presence and position of certain natural cross-bonds. Yet this loose distinction of position of stone-cubes under experimental pressure, "on bed" and "on edge," which was sufficient for the purposes of twenty years ago, will need hereafter to be supplanted by close discrimination, in the quarry from which the cubes are derived, of the true planes of tension, compression and stratification, which are not necessarily connected either with the horizontal or vertical division-planes in the stratum or with the lines of lamination or fissility in the specimen.

The relative weight of a volume of stone, taken in mass and including its empty cavities or "voids," the factor of practical importance to the builder, depends chiefly on mode of interlockment of its grains and consequent degree of consolidation, rather than on the specific gravity of its constituents. This becomes at once apparent by comparison of the specific gravities of the common minerals in building-stones and of the stones themselves, viz.:

Quartz	2·65	Sandstone	2·6
Feldspars	2·5–2·8	Limestone	2·6–2·8
Micas	2·7–3·2	Slate	2·5
Hornblende	3·–3·3	Granite	2·6–2·7
Calcite	2·5–2·8	Marble	2·6–2·8
Dolomite	2·8–2·9	Dolomite	2·8–2·95

The slight variations here stated, except in the rarer minerals, hornblende and iron-micas, show clearly that the actual weight of a definite bulk of stone depends almost entirely on the amount of its voids and of the cementing material which may occupy them.

II. COHERENCE.

Independently of the connection between grains of stone produced by interlockment, two modes of coherence prevail, each mainly characteristic of one or other of the two classes of building-stone, *cementation* and *molecular cohesion.*

(1) *Cementation*, mainly prevalent in the fragmental stones. The most common cementing materials in freestones are iron-oxides, clay and silt, but these are among the feeblest, except when uniformly diffused in minute films among closely abutting grains—the form in which, in the arts, even a feeble cement becomes tenacious, whether it be the mucilage of the stationer, the glue of the cabinet-maker, or the mortar of the mason. The cement is often unequally distributed, *e. g.*, in the sandstone of Corsehill, Scotland (*Fig. 18*), heaped together in the larger cavities, and, to a large extent, absent or scanty among the finer interstices where alone its binding power could be effective.

In other cases there is a great excess of cementing clay crowded into all the cavities, and even wedging apart the grains in thick plates, crusts and lumps, mixed with finer sand, often shown in the brownstone of Portland, Conn. (*Fig. 8*). The poorest of all cements are the kaolinic clays; better than these, the ferruginous clays* and the amorphous and granular iron and manganese-oxides, all of common occurrence. The last become powerful cements only when they occur in crystalline form, as fibrous films and crusts of magnetite, hematite, limonite, turgite and pyrolusite. Such sandstones with crystalline cement are not common, often irregularly tinged or blotched by ochreous clouds, not always freestones, and less popular on that account, but they are among the best of our building materials.

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*Through Dr. Heinrich Ries, of Cornell University, I am informed of the following experiment, stated to him by Prof. S. H. Babcock, upon the brownstone of Oswego, N. Y., a poorly cemented and friable sandstone, which contains as cement ferruginous clay in excessive amount, and which possesses a crushing strength of 2,400 pounds to the square inch. After baking a cube of this stone in a brick-kiln for the usual period, two or three weeks, it was found to possess a crushing strength of 12,000 pounds, evidently from conversion of its clay-cement into brick.

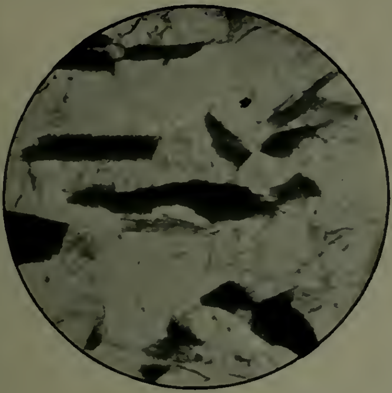

Fig. 7.—Biotitic Gneiss.—New York City.

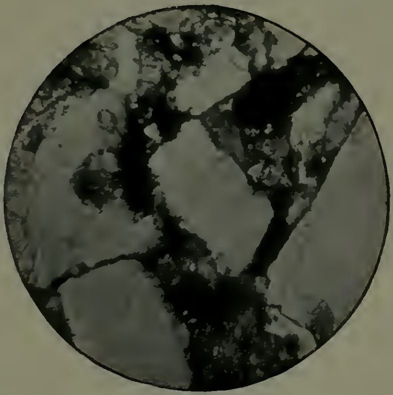

Fig. 8.—Sandstone (Brownstone).—Portland, Conn.

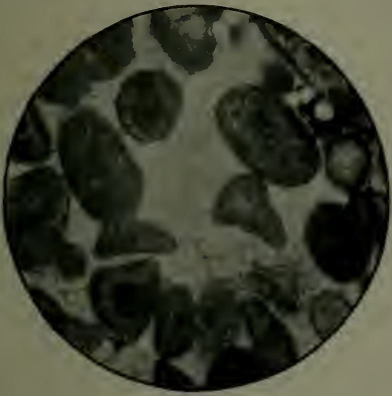

Fig. 9.—Oolitic Limestone.—Bedford, Ind.

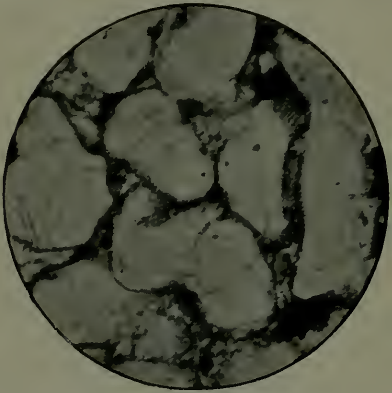

Fig. 10.—Quartzitic Sandstone.—Potsdam, N. Y.

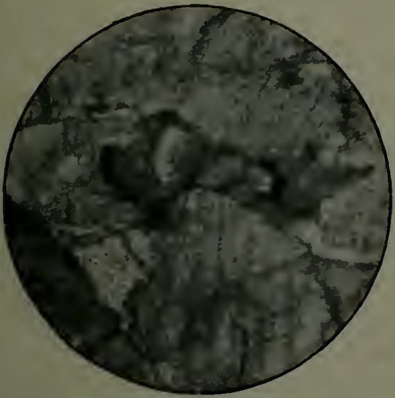

Fig. 11.—Shell-Limestone.—Lockport, N. Y.

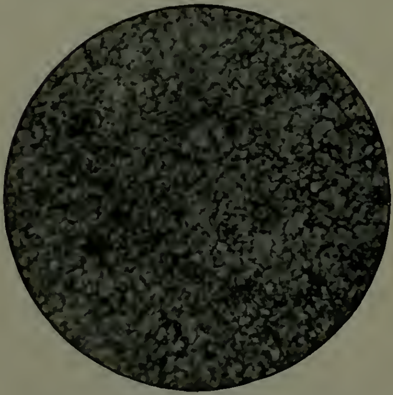

Fig. 12.—Limestone.—Radnor Station, Pa.

Plate B.

Fortunately, the lack of cementing power of the true clays is remedied, in many cases, by their marly character, and to this invisibly diffused content of lime-carbonate is due the credit ordinarily given to the visible kaolin and iron-oxides in the interstitial cement. When this is dissolved out by weathering the cementing clay softens, the stone becomes pulverulent and disintegrates into sand. Minute crystals of calcite have been occasionally detected in the cement of the Connecticut and New Jersey brownstones, and it is probable that magnesia and iron-carbonates also lend their aid.

Lime-carbonate, like iron-oxide, becomes a strong cement only when found in crystalline veinlets. Thus, the Caen-stone or oolite of Southern Europe, the favorite building-stone used in the great cathedrals of the Old World, is a soft, granular, very cellular and earthy sponge. When introduced into the cities of the Eastern United States, its rapid disintegration astonished prominent architects who had been leaning upon European experience. Its preservation and survival for a short term of years were secured only by repeated coats of paint. From continuance of this absurdity we have since been saved by the recognition and introduction of the better class of so called oolitic limestones of our Western States. In these the rounded organisms (foraminifera) and tiny concretionary spherules and lenses may be but partially cemented together, the intervening cavities in large part unfilled and visible to the unaided eye (*Fig. 3*), and the crushing resistance only about 6,000 to 7,000 pounds to the square inch. But elsewhere in the same region the interstices of this rock, as at Bedford, Ind. (*Fig. 9*), though still larger, are completely occupied by calcite in crystalline veinlets, often pure and limpid; to their binding force, the great compactness of the stone, probable durability and high compressive resistance, 10,000 to 12,000 pounds to the inch, are mainly due.

The most powerful of all cements is silica, which in the form of compact crystalline quartz, binds together a large part of the otherwise loosely pulverulent sandstones of the Cambrian and Lower Silurian formations into solid quartzites. From the point of strength and durability, these supply us with one of the most satisfactory building-stones, the quartzitic sandstones of the Northwest, of Lumberville and Mauch Chunk, Pa.,* and of Potsdam, N. Y. (*Fig. 10*). It can be readily dressed, it is true, only soon after extraction from the quarry; it quickly hardens by drying out of the quarry-sap, even during transportation to market; it cannot be treated as a freestone, and the building world usually rejects it and stones of its class (like the excellent Craigleith stone of Great Britain) as too hard and too costly for modern needs. Is it not a sorry matter that, not the pencil of the architect, nor the design of the engineer, nor even the true economy and interest of the builder are called on to-day to decide on the choice of the best stone, but the tenderness of the edge of the stonecutter's chisel?

The remarkable strength of a stone, like the one just described, is plainly due to the nature of its interstitial cement, rather than to that of the main material. The visitor to the great castle at Heidelberg, Germany, and also to a smaller, on the summit of the mountain across the Neckar, will notice, on examining the great piles of masonry blown up by the armies of Louis XIV, that the walls have fallen in solid masses without crumbling, the fractures cutting straight through both the stone blocks and their intervening seams of excellent mortar. In contrast with this, the frequent weakness of the natural cement among the grains of a stone is well disclosed in a thin section of Potsdam sandstone, in poorly consolidated form, from the region along the tributaries of the Upper Mississippi. In this arenaceous sandrock (*Fig. 4*) the grains are barely cemented together with a little iron oxide. The line of weakness will be recognized, in the crumbling thin section, by the divergence of the crack in and out around the grains of quartz, following the film of weak cement.

In the crystalline stones also, even the granites, there is good reason to suppose that some cement may be often partly concerned in their strength. One evidence of this is the effervescence caused by application of an acid in many specimens, sometimes accompanied by loss of coherence and strength. This testifies to the diffusion of lime, magnesia and iron-carbonates through the interstices, though in forms rarely detected by microscopic examination. There is also significance within the coarser limestones (*Fig. 11*), marbles (*Fig. 17*), and granites (*Fig. 2*), whose grains may be an inch or more in diameter, in the delicate, light colored films and crusts of calcite, aragonite, hyalite, pyrolusite, etc., familiar to the mineralogist and petrographer. These become readily apparent to the naked eye by reflected light on the surfaces of opened fissures and cleavage-planes, though of course hardly distinguishable in stones of finer grain.

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* Hopkins, *op. cit.*, 86, 91.

Again, we know that if the quarry-sap or natural interstitial juice of a building-stone is allowed to remain in a freshly quarried block, left exposed to the winter cold, its expansion by frost produces the "rifts" or "checks" with which the stone may become seamed and ruined. For this reason, as well as on account of the objectionable staining often produced by its evaporation, and even the surface disintegration of masonry sometimes caused in part by its efflorescent crusts, the quarry-water in building-stone may act as a source of injury. Yet, on the other hand, to this same evaporation the rapid and desirable hardening of the surface of many varieties of stone is indebted, after a short exposure to the air, either in hewn blocks or on the quarry-face.

Such facts indicate that the grains of even a crystalline building-stone owe their mutual coherence, and the rock its strength, in part to cementation by films of solid matter deposited in the interstices from infiltrating solutions or quarry-sap. Is it not surprising to remember that as yet we know nothing with certainty concerning the varying nature of this important liquid—often the very life-blood of a valuable building-stone! We may conjecture, indeed, with high probability that, in the deposited films, lime, magnesia, iron and manganese-carbonates and iron and manganese-oxides are common, that lime-sulphate often occurs, and that silicates of soda, potassa, lime, magnesia and other bases, and even dissolved colloid silicic acid, crystallizing as quartz or amorphous in the form of chalcedony or hyalite, also generally serves in the office of cementation. Thus the dendritic and concretionary films, which on joints, seams and fissure-planes supply the rare curiosities of crystallization, the charming arborescent or stellated *bric-a-brac* of the mineral collector—rock crystal, opal, hyalite, aragonite, siderite, limonite, pyrolusite, zeolites, serpentine, epidote, etc.—offer, in the microscopic forms of their dissemination, humble and essential service in welding together both the strata and the constituent grains of most kinds of stone.

(2) *Molecular Cohesion.*—It is in the crystalline stones chiefly that coherence between the grains is greatly increased by another physical force, molecular cohesion, that which exists between surfaces of all solids pressed into intimate contact. With this force we are familiar in the close coherence of smooth surfaces of glass sheets, especially of polished plate-glass. In consequence of the tremendous force here involved, that of capillary adhesion, such surfaces may cohere so strongly that, on application of sufficient pressure for detachment, the very surfaces themselves may be torn away. This cohesion is reinforced to a small extent, about 16 pounds to the square inch, by atmospheric pressure. A block of a crystalline stone comprises an innumerable quantity of minute planes in close adherence; especially is this the case in those sheared forms of rock in which original coarse grains or crystals have been crushed into plates, whose small cleavage-faces, absolutely clean at the moment of splitting apart, have been at once squeezed and welded together under intense pressure. It is probable that increased compressive strength may accompany increasing fineness of grain, for instance, in series of granites, from coarse granite at one extreme (as in *Fig. 2*), through brecciated forms down to a fine granite, granite-porphyry or felsite, at the other; this result, suggested by study of reported tests, may have been produced not only by more intimate interlockment of grains, but by the subtle physical force of capillary adhesion.

The marbles and dolomites exhibit the same congeries of tangent planes and correspondingly high compressive strength. The flexibility of these stones, many instances of which I have elsewhere recorded,* and their actual plasticity, as confirmed by the recent interesting experiments on artificial compression of marbles, by Profs. F. D. Adams and J. T. Nicholson† at McGill University, Montreal, are accompanied in nature, during compression, shearing and flow of the stone material, by no tendency to loss in coherence and strength. This is the more strange, since the internal motion implies a sliding or play of the grains to some extent over each other, with sufficient friction and attrition, in cases where solution and recrystallization have not ensued, to have produced a partial rounding of many grains sometimes distinguished in a thin section of dolomite or marble, a structural condition in which there is clear evidence of imperfect interlockment and of little possible cementation. Yet there often remains an enormous compressive strength, which, in some limestones and dolomites, reaches 25,000 pounds to the square inch, beyond that of most granites.‡ Over this puzzling anomaly an English writer thus expresses his views: "It is not merely the nature of the constituents or their mechanical mixture that gives dolomite its good qualities; there is some peculiarity in the crystallization which is all important. In the formation of dolomites, some peculiar combination takes place between the molecules of each substance; they possess some inherent power by which the invisible or minutest particles intermix or unite with each other so intimately as to be inseparable by mechanical means."§ In my opinion, it is not the chemical combination here pointed out which is concerned in resistance to crushing, but the peculiarity in mechanical mixture or texture, in both marbles and dolomites, resulting in surface cohesion of an enormous number of minute crystalline plates.*

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* Tenth Census of U. S. (1880), X, Report on Building-Stones, 366-367. See also observations of A. Winslow on the bent marble slabs in a cemetery (*Am. J. Sci.* (3), XLIII (1892), 133).

† Stone, XVI (1898), 349, and Science, VII (1898), 82-83.

‡ N. H. Winchell, Geol. Minn., Final Rep., I (1884), 156.

§ "Notes on Building Construction," So. Kensington Series, Pt. III, 58.

Even in fragmental stones, the same increase of strength with multiplication of contact-planes is often indicated, especially in the more finely brecciated forms of limestones, brecciated sandstones, quartzites and flags (*Fig. 6*). In the coarser limestones, such as that of Lockport, N. Y. (*Fig. 11*), originally brecciated aggregates of broken fossils, an inferiority in strength and durability is manifest, which seems to be caused chiefly by imperfect coherence of these grains with rounded outlines, among which fine cracks consequently run in an interlaced system; the weakness may be increased by the coarse cleavage-structure commonly developed within the grains themselves.

In the finer semi-crystalline limestones, like that of Cream Valley, near Radnor Station, Pa. (*Fig. 12*), the important relationship between size of grain in a stone and its strength (and probable durability) is presented in the multiplication of facets. In a similar minutely crystallized limestone of Lake Champlain, N. Y., the crushing resistance reaches 25,000 pounds to the square inch.

An important exception occurs, however, to connection of durability with minuteness of texture, in limestone or dolomite, in intermixture of organic and aluminous matters, especially bluish clay. This constituent ordinarily occurs in the form of thin shaly layers, alternating with others of purer limestone. Even though the compressive strength of the entire stone may reach 20,000 pounds to the inch "on bed," the eager absorption of moisture by the clay and oxidation of its iron-protoxide produce a softening, cracking and disintegration, hastened by alternations of soaking and drying, of freezing and thawing, which render these common argillaceous varieties of limestone and dolomite the poorest of building-stones.

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* From the retention of form by the grains of this mineral, in spite of the pressures generated during dynamic metamorphism, as shown by their sharply defined polygonal outlines, in a thin section of dolomite-marble under the microscope, Vogt concludes "that the extraordinarily high compressive resistance displayed by dolomite-marble is probably connected with the fact that dolomite possesses a very high power of resistance to mechanical deformation."—*Loc. cit.*, p. 16.

The fine granulation of a stone, also, may favor absorption of moisture, introduction of corrosive vapors and liquids, crumbling and exfoliation, under the attack of the weather and frost, on account of the more ready loosening and displacement of successive fine grains; partly because interlockment is less intricate in fine than in coarse grains, and partly through the action of capillary interstices, the grains in some stones not lying in intimate contact.*

The absorption-coefficient of stone toward liquids depends partly on the forms and abundance of its interstices,† and partly on the porosity and abundance of the natural cement which may occupy them. As to the former, it is important, for my present purpose, to distinguish two classes of interstices,‡ well shown, from their equal distribution, in the sandstone (grès) of Beauchamps, France (*Fig. 13*). (1) The fine *seams*, which make up the close network of intersecting fissures, cracks or contact-surfaces in and between the grains or crystals; these are largely of capillary

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* From the study of churches, etc., in Northern and Western Norway, even six or seven centuries old, it has been ascertained that massive coarse-grained (regional metamorphic) marble is better suited for use in the open air than the compact or fine-grained Carrara marble, on account of the much smaller surface exposed to attack among its coarse grains.—Vogt, *loc. cit.*, 49.

† The openings of rocks in general, viz., tubes and sheet-passages (such as those furnished by faults, joints, etc.), have been thus classified (C. R. Van Hise, Bull. Geol. Soc. Am., IX (1898), 272):

Larger than capillary,	Tubes, diameter over 0·508 millimeter. Sheet passages, width over 0·254 millimeter. Water-movement, by ordinary laws of hydrostatics.
Capillary	Tubes, less than 0·508 millimeter. Sheet passages, less than 0·254 millimeter. Water movement, by laws of capillary flow.
Sub-capillary . . .	In which molecular attraction of solid material extends from wall to wall. Tubes, less than 0·002 millimeter. Sheet passages, less than 0·001 millimeter.

‡ "A Study of the New York Obelisk as a Decayed Boulder," Annals N. Y. Acad. Sci., VIII (1893), 158, 159.

breadth, and, in part, cross the grains themselves in the finest cleavage-clefts, and in fissures generated by crushing. (2) The angular *pores*, or cavities, in part, tubules and widened cracks, occurring at intersections of the seams, often of notable volume up to that of an actual cellular structure, in the more loosely compacted and arenaceous kinds of stone, especially sandstone and cellular limestone (*Figs. 3* and *9*).

Where a cement occurs, it occupies chiefly the pores, in amorphous, finely granular or crypto-crystalline, closely packed masses (*Figs. 8* and *5* and *Fig. 14*), many seams remaining empty or only coated in parts by cement in thinnest films (*Figs. 4* and *18*). The absorbent capacity of stone toward a liquid is affected chiefly by the volume of permeable pores and seams, and diminished by the amount of obstructing cement. Rapidity of absorption depends upon the area affording capillary action; if the interstices are free from cement, largely upon the seams; if a spongy cement is present, upon its additional though slower increment of capillary force within the pores as well as the seams.

The destructive expansion, caused by ice-films within a stone, is due in my opinion mainly to the large ice-flakes occupying deeper clefts and pores than to the minute films occupying superficial seams; on the principle of the more destructive efficiency of the swollen ice confined within the expanded part of a bottle than that of the slender ice-cylinder which is thrust out of its narrow neck.

If these conclusions are correct as to the differing influence of pores and of seams upon the absorption-coefficient of stone and upon its mode of disintegration by frost, the methods of testing absorption should be so modified as to make this interstitial distinction. Such a modification I believe to be approximately practicable. In any case the difficulty of disentangling minute air-bubbles from the complicate network of capillary passages, if once partly occupied by water, should show the imperfection of the common method of determining the saturation-coefficient of stone by immersing the test-cube in water or covering it at once with

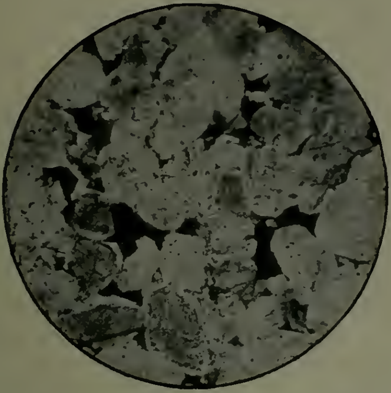

Fig. 13.—Quartz Sandstone.—Beauchamps, France.

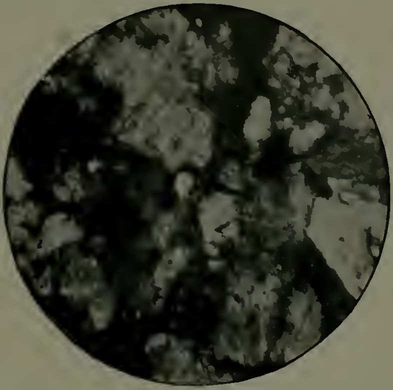

Fig. 14.—Sandstone (Brownstone), Paterson, N. J.

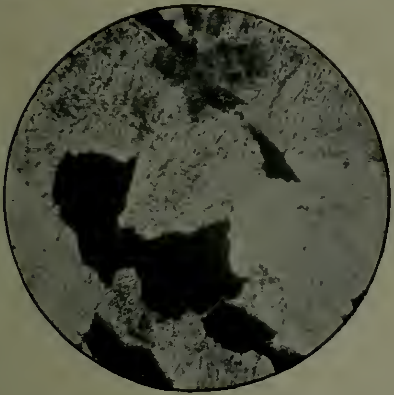

Fig 15.—Granite.—St. Cloud, Minn.

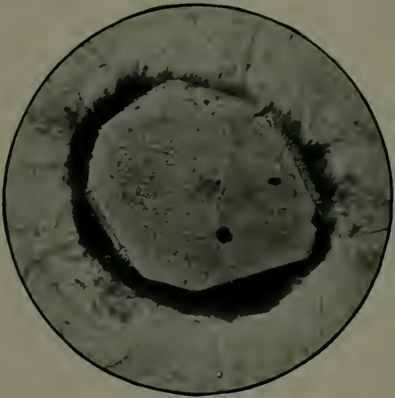

Fig. 16.—Garnet in Muscovite.—Wieser Mt., Id.

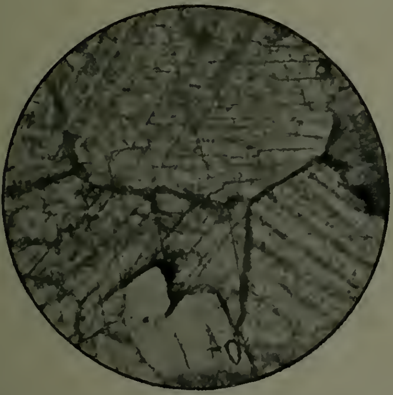

Fig. 17.—Dolomite-Marble.—Tuckahoe, N. Y.

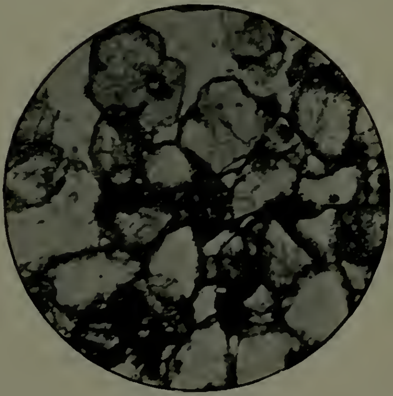

Fig. 18.—Sandstone.—Corsehill, Scotland.

LEVYTYPE CO., ENGRAVERS AND PRINTERS, PHILADELPHIA.

Plate C.

water; the preferable method is by soaking upward from a wet tile at the beginning of the test.*

In certain kinds of stone, a tendency to partial solution in atmospheric waters is closely connected with their lack of coherence and durability. The most prominent example is presented in ordinary limestone, consisting of imperfectly crystallized or amorphous carbonate of lime, the most soluble form of that substance, and that too in granular or earthy condition and thus offering the largest possible area for permeation and attack by a solvent. The vast amount of surface and subterranean erosion and solution, carried on in all limestone regions, is too well known to need any present description.

The earthy magnesian limestones offer as little resistance to erosion. But with crystalline forms, the marbles and dolomites, the extent of solution and erosion becomes greatly diminished and generally quite superficial.

An exception occurs where the solvent action has become reinforced by increased acidity, as in rain-waters of city atmospheres polluted by smoke from combustion of pyritous coal. These have been found to contain sulphuric acid, to the gallon, in London, 1·43 grains; Liverpool, 2·77; Manchester, 2·91, and New York, 4·85. The last figure is founded on a single determination for forty-one days,† and it has been estimated by the same investigator that the 4,500,000 tons of coal annually burned in New York City discharge into the air 78,750 tons of this acid. However, an impression prevails that the increased attack upon the building-stones of a large manufacturing city is partly due to increased proportions of carbonic acid in its atmosphere. In behalf of this opinion, reference has been made‡ to the following proportions of that gas in 1,000,000 parts of the air in various cities, viz.: Liège, 335; Boston, 385; Cambridge, 337; Washington, 387 to 448; Berlin, 390 to 450; Manchester, 442. However, as the mean content of carbonic acid in the general atmosphere is accepted as about 400 parts, with variation from 300 to 620, according to different authors (and even to 1,110 on Mt. Blanc, according to Frankland), the evidence is against its concentration, except in barely perceptible proportion, in the open air of any city. Nevertheless, during certain foggy conditions of the atmosphere, when the condensed vapors of a city lie over it in an undisturbed bank, it may yet be found that carbonic acid is associated with the other acids in increased proportions at such periods, in both the air and the rain waters, to assist in the corrosion of stone.

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* "A Study of the N. Y. Obelisk," 159–160.

† T. Egleston, "The Cause of Decay of Building-Stone," *Am. Arch.* (1885), 5.

‡ G. P. Merrill, *op. cit.*, 359, and Vogt, *loc. cit.*, 47.

In the sandstones, the general marly constitution of the cement or dissemination of iron-carbonate and the loose spongy texture of the stone supply conditions specially favorable for solution and disintegration, *e. g.*, in poor varieties of brownstone, such as one from Paterson, N. J. (*Fig. 14*).

In granites and stones of that class, the minerals with iron partly in ferrous condition, feldspars, iron-micas, chlorite and hornblende, are subject to notable amount of solution, as well as of attack and injury in other ways, by the agencies of weathering. This is especially marked by the quick discoloration and deep decay of the tremolite, rich in ferrous oxide, which abounds in the coarse dolomites of our Eastern States.

The process of solution of constituents during submersion of stone, especially that by the action of sea-water, is of important concern to engineers, as affecting both foundations and lower courses of masonry in piers and abutments of bridges, docks, light-houses, fortifications, etc., along the sea-coast. Yet on this subject there appears to be no record of experimental investigation, and we have no definite information whatever. For example, in the attack of sea-water on the mortar or other artificial cement between blocks of stone, on the marly natural cement in the interstices of a sandstone, and on the general calcareous material of a limestone or marble, may we assume that the chief reaction is the production of calcium sulphate as a protective coating, or that continuous solution, corrosion and destruction of the material ensues?

As to the resistance of coherence in building-stone to weathering, the methods of trial or test are very numerous and belong to two classes, artificial and natural.

An artificial method, if thoroughly satisfactory, must cover all the complex processes by which the disintegration of stone is ordinarily effected, viz.: the solution of part of its ingredients by circulation of sap through its interstices, the swelling and splitting of others by absorption of oxygen and water, and the mechanical rending apart of superficial grains by alternations of temperature and by expansion of ice-films. It must be further adapted to the widely different degrees to which each of these three processes—solution, absorption and disruption—affects the different kinds of stone. Thus a method founded on solution (such as treatment of cubes of stone by carbonic acid or by weak hydrochloric acid), or on oxidation and solution (as by exposure to acid fumes) entirely neglects the other process, and must be worthless in application to the stones of entire solubility, the limestones, dolomites and marbles. A method only efficient in mechanical disintegration (such as exposure of stone-cubes to alternations of freezing and thawing) is equally imperfect, especially with varieties whose cement or whose grains are peculiarly subject to solution or to chemical decomposition. Even in more complex methods of trial (such as Brard's, with sodium-sulphate), in which disruption is produced by means of the crystallizing salt, and, as well, some indefinite degree of solution, none of the subtle attack of chemical reaction is well considered. It is obviously doubtful if any artificial method of universal application can ever be devised for exact determination of degree of coherence in rock-grains under atmospheric attack. Yet we may hope for the development of artificial methods of trial, of satisfactory application to special kinds of building-stone, after these methods have been thoroughly *standardized*, in comparison with the natural evidences of durability and with the results of general tests of that property on a full series of the important building-stones of the world.

The unsatisfactory character of even the artificial methods of limited application has frequently led to their rejection, in recent years, in favor of the natural methods.

To one of these, the study of natural outcrops and of ancient artificial exposures of a stone in vicinity of its quarry, with careful observation of both character and depth of its weathering, decided preference has been often expressed by writers on the subject. But this natural method also is attended by special difficulties, which it may be well to illustrate by recent observations at Tuckahoe, N. Y.

The dolomite-marble of that region (*Fig. 17*) occupies only the eroded bottoms of the narrow valleys. Abundant outcrops of that rock occur along the edges of the quarries, covered by a crust of deeply decayed and discolored material, often passing into dolomitic sand. Yet this apparent evidence of the mode and extent of its weathering cannot be fairly accepted, since all these present outcrops merely indicate the recent stripping of an ancient surface of dolomite, long subjected to the action of peaty waters, rich in organic acids, derived from swamps, bogs and accumulations of humus which once overlay the bottoms and slopes of all these valleys. In evidence of true weathering, not a single satisfactory outcrop was found.

Another exposure of deeply decayed gneiss in a cross-valley, running east and west, possessed as little significance, in comparison with other beds of fresh gneiss outcropping on the adjoining hillside. The former merely represented a remnant of the ancient continental surface decayed during the vast pre-Glacial Period; its escape from removal by glaciation was due to its sheltered situation.*

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* In the region south of the glaciated belt it is obvious that still greater uncertainty attends this method of diagnosis. During the interval between the reading and publication of this paper, the following good illustration of this point has been put on record: "Investigation at the quarries, where a considerable depth of decomposed rock is seen to overlie the more marketable material, suggests the suspicion that the Port Deposit granite will not withstand atmospheric agencies for any great period of time. This deceptive appearance arises from the fact that the crystalline rocks southward from Philadelphia have not been scoured and cleaned by the action of glacial ice as in more northern latitudes. Thus the overlying waste represents the decomposed products of several geological epochs, perhaps reaching back as far as Cretaceous time."—E. B. Mathews, Maryland Geol. Survey, II (1898), 145.

Again, at Sutherland Falls, Vt., the perfectly fresh unstained surface of a white marble outcrop bore equally untrustworthy evidence in its behalf in comparison with the rusty eroded crust of another bed on a hill-top above. The high glacial polish and sharp striæ upon the former proved that it had not been long uncovered from the heavy protecting coat of glacial clay common in the vicinity.

It appears, therefore, that this natural method is attended by as many difficulties as any of the artificial, and that it calls for as much exercise of careful judgment in consideration of the past history of any exposed outcrop of rock, whether it has been subjected, how long and how recently, to exposure to weathering; to that excessive trial during pre-Glacial time; or to the subsequent planing and cleaning by the Continental Glacier; or to long protection by loose porous or by compact overlying deposits of unknown thickness; or to attack by acid swamp-waters; or to frequent cleansing by heavy rainfalls, as on mountain-tops, by local streams or by the higher tides or storm-waves of neighboring waters; or to the attrition of sands swept over by desert-winds; or to artificial protection or uncovering, as by roadsides, within the historic period.

The other natural method of determining the resistance of a stone to weathering—and one which, when available, under known conditions and of sufficient antiquity, may be, perhaps, the most satisfactory of all—consists in the study of weathered surfaces of ancient stone buildings and monuments. Yet this, too, may easily lead to error, unless due attention be paid to the many varying influences which may have affected the exposed surfaces in question; subjection to dampness, to street dust, to soil acids, to acid vapors, etc., within a few feet of the ground, or to a purer air at a higher level; to the afternoon sun, to continued frost or to frequent thaws, to certain prevailing rains and winds on the different sides of a building; to the purer atmosphere of a rural or suburban locality, to the air of a city tainted by acid vapors, chimney-soot or fumes from factories; to salt fogs from the sea, flying sand from beaches or arid deserts, the action of lichens and other vegetable growths, protection by foliage, the influence of the original dressing of the masonry, especially on well tooled or bush-hammered surfaces, etc.

It is apparent, therefore, that the elements of strength, on which the coherence of the grains of stone depends, in resistance to weathering, are so varied, that with many kinds no single known method, artificial or natural, can be relied upon without question and without confirmation. We yet need to seek for light through comparison of results from all promising methods of possible application, and often to gratefully accept even an approximation to the truth.

[*To be concluded.*]

Stated Meeting, Wednesday, February 8, 1899.

SUBTERRANEAN ICE DEPOSITS IN AMERICA.*

By Edwin Swift Balch.

The whole subject of subterranean ice is so bound up with questions of temperature that it seems well to say a few preliminary words about underground temperatures in general. Underground temperatures may best be studied under three heads: the normal, the super-normal and the sub-normal. The normal or ordinary temperatures scarcely change the whole year round. There is a superficial layer of soil or rock, of but very slight depth, which is affected by the outside temperatures; beneath this there is usually a layer, the temperature of which is about that of the mean annual temperature of the locality; below this the temperatures increase slowly with increasing depth below the surface. This increase may be roughly stated as about 1° C. for every 32 meters in depth. Super-normal temperatures at or near the surface are very rare, and are due to special causes. Thus, there are a few caves which have temperatures much above the mean annual temperature of their locality. In such cases, the heat is generally due to the presence of hot

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* Copyright by E. S. Balch, 1899.

springs or to volcanic action in the immediate neighborhood.* Sub-normal temperatures in the superficial layer are rare, but less so than super-normal temperatures. These temperatures may be abnormally low without descending to the freezing-point. Sometimes, however, they are so low as to be accompanied by the formation of ice.

For some years I have been collecting all the data I could find about subterranean ice deposits in America. Scientific journals, one or two books of travels, and cuttings from local newspapers, have furnished information about a number of places, and correspondence with persons residing in their neighborhood has given more. My notes include over fifty localities ranging from Greenland to Tierra del Fuego. Much of this information comes from the reports of trained observers, such, for instance, as the paper of Lieutenant Cantwell, describing the ice cliffs on the Kowak River. About the accuracy of most of the information I feel but little doubt, except in regard to the measurements given, concerning which there is a tendency to report things underground as much larger than they really are.

On the west coast of Greenland a number of buried glaciers are reported.† These seem to occur when a glacier finds its outlet in the sea and for some reason stops flowing. Then some of the Arctic mosses and lichens, which flourish in spite of the cold, gradually make their way over the ice, first in thin layers, later in thick masses, the young plants trampling down the older ones until the latter turn to a rich mould. The seeds of grasses and flowers find their way to this until the whole plateau becomes a garden of green, gold and white.

Much frozen soil is found in Alaska. Prof. Israel C. Russell saw many strata of ice in the banks of the Yukon and he says that strata over 30 meters thick have been found. Much of the Klondike country is frozen down to bed rock, 8 or 10 meters deep. In this case the miners are said to cut off the moss with a shovel, and then to build a fire which thaws out the ground for 5 or 10 centimeters. They dig this out and then start another fire and continue the process. At the other end of the continent, in Tierra del Fuego, ice and lava are said to be found inter-stratified for a great depth, each winter's snow being covered by a new lava sheet. On Chimborazo also, Humboldt says that enormous heaps of ice are found covered with sand and far below the inferior limit of the perpetual snows.

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* F. Kraus, *Höhlenkunde*, p. 86.

† W. E. Meehan, *Philadelphia Ledger*, 1896.

In our Western States there are several caves which retain ice, and which are of considerably larger proportions than any in the East,* and there is no doubt that more will be discovered in the future. Places where ice remains, whether caves or not, are reported from Washington, Oregon, California, Montana,† Wyoming, Colorado and Arizona. A particularly interesting place in the State last named was brought to my notice by the distinguished archæologist, Mr. Frank Hamilton Cushing. It is a cleft in a lava bed, which, being roofed at the further end, might be described as a cave. In this the ice remains until June or July, much later than anywhere else in the neighborhood. The Zuni Indians have a mystical feeling about this, calling the ice the breath of the gods; the snow they consider a sort of down. The region is very arid, and water very precious, to which fact the association of the supernatural with the occurrence of snow and ice among the Indians may be explained.

In the States east of the Rockies some thirty-five subterranean ice deposits are known—in Maine, New Hamp-

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* One of these is in Washington. It is a lava cave, and is 56 kilometers from the mouth of the White Salmon River. Described by R. W. Raymond, *Overland Monthly*, November 3, 1869, p. 421. Another is on Cow Mountain, near Cripple Creek, Col.

† Mr. Robert Butler, of San Jose, Cal., wrote to me that he had examined a glacière cave and a freezing well in Montana, where such wells are not uncommon. The people in the neighborhood think the ice forms in summer. Mr. Butler investigated the question of cold-air draughts coming from these glacières. He found that, on rapidly walking into them on a hot day, the same sensation was produced as though one were standing still and the air were in motion. He also satisfied himself that, as far as he had observed, the ice was formed by no other cause than the natural cold of winter.

THE BLUFF AT DECORAH, IOWA. LOCATION OF CAVE ABOVE WHITE CROSS. (Photo. by Mr. A. F. Kovařik.)

shire, Vermont, Massachusetts, Connecticut, New York, Pennsylvania, Virginia, Indiana, Missouri and Iowa. The most southerly of these is in about 37° north latitude. The deposits in Arizona, which are yet further south, are at a much greater altitude.

Four of these only may properly be called caves. These are at Manchester, Vt., Ellenville, N. Y., Farrandsville, Pa., and Decorah, Ia. The little cave near Manchester is in a marble formation, and, so far as I know, it is the only marble cave in the world where abnormally low temperatures have been found. On the 5th of July, 1898, there was plenty of snow in it, but nothing that would strictly be defined as ice.

At Decorah, Ia., is a little cave or limestone fissure on the banks of the Iowa River. It is quite famous because the capillary theory—that ice might be formed by pressure on the water dripping through rock cracks—was formulated to explain it. On the 30th of September, 1898, there was no ice in it, and the temperatures were normal. Neither were there any tiny tubular fissures visible, but instead of these, there were quantities of fossils.*

Near Ellenville, N. Y., is a cave—or perhaps more correctly a gorge, as it is minus a roof—which is the largest natural refrigerator in the Eastern United States. Several friends of mine have found snow and ice in it in past years in July and August. Last year, on the 9th of October, neither snow nor ice was present, and the temperatures were only slightly below that of the outside air in the shade.

In Clinton County, Pa., on the banks of the Susquehanna River, opposite to the village of Farrandsville, is a mite of a cave.† It can only be entered for about 2 meters, although there are several cracks leading further into the rocks. The postmaster and the railroad agent at Farrandsville assured me that ice was never visible there in winter, but that it was found there from April, usually all through the summer months. On October 11th, there was no ice in sight, but after fifteen minutes' exposure, the thermometer dropped to 6° C., an abnormal result, showing, in my opinion, the presence of ice further in. The rocks also were abnormally cold.

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* Mr. Alois F. Kovarik, of the Decorah Institute, published a valuable series of observations about the Decorah Cave, in the *Scientific American Supplement*, No. 1195, November 26, 1898. He thinks that the cold of winter is the source of cold.

† This could also be described as a windhole.

Of rock gorges which act as refrigerators I have seen three in the Eastern United States. One is the, so-called, Ice Glen at Stockbridge, Mass. I was told that ice remained there later than elsewhere in the neighborhood, sometimes as late as May. On the 3d of July there were no trace of ice or snow, and the temperatures were normal.

There is a great gorge near Randolph, N. H., north of the Presidential Range, between Crescent and Black Mountains. This is called the Ice Gulch. The sides are quite sheer in many places, and the bottom is choked with an accumulation of boulders. Among these there was a small quantity of ice in one or two places on the 11th of August last. This ice was unusual in formation, neither solid nor prismatic, but full of air bubbles. It crumbled away in small pieces under the teeth.

In the Presidential Range itself is the great King's Ravine, on Mount Adams. The bottom is covered with huge boulders, and among these, some years ago at the end of September, there was plenty of prismatic ice.

There are a number of rock taluses in the Appalachians, where ice is found. One of these is on Lower Ausable Pond, in the Adirondacks, at the north base of Mount Sébille or Colvin. It is a huge talus of great Laurentian (?) boulders, among which are numerous hollows, which might by courtesy be called caves. On the 12th of July, Mr. E. I. H. Howell went with me to this spot, and in three hollows we found ice, in two of these places in considerable quantities. Mr. Howell has been repeatedly at this spot during past summers and always found ice, so it must be considered a perennial glacière.

Two days later, on the indications of Mr. Otis, the chief guide of the Adirondack Reserve, I explored the south talus of the Giant of the Valley. In two places about 1 kilometer apart, and in each case in hollows among the boulders there was plenty of ice. I did not follow the talus throughout its whole extent, as the walking was fearfully bad, but apparently ice might be expected anywhere, as I found it at once at both places I inspected. One mass was certainly 5 or 6 meters long by 2 in width and 1 in depth. The ice was very pure, hard and non-prismatic. In one of the hollows, where there was only a little ice, the thermometer registered 6° C. after fifteen minutes' exposure, about 1 meter from the outside, and about 1 meter from the same spot in the shade of a tree, it registered 26° C., a difference of 20° C. within less than 2 meters.

Near Rumney, N. H., is a boulder talus where Mr. John Ritchie, Jr., Secretary of the Appalachian Mountain Club, of Boston, some years ago found ice in August. The Sheriff of Rumney accompanied me to this place, and said that ice was generally abundant there in summer. On the 18th of August we found none and the temperatures normal.

At Watertown, N. Y., under the tracks of the New York Central Railroad, are some rock cracks, in front of which cellars have been built, and these are used to store beer barrels. On the 12th of September there was no ice in the cracks, and the lessor of the cellars told me it had all melted away early this summer, on account of the great heat. Near Watertown is the picnic ground of Glen Park, where there is a hollow or rock basin, where ice and snow sometimes lie over until July. There are cracks in the rock sides of this hollow, in which ice remains over near the mouth, but it is not found any distance within.

An hour on foot to the north of the Pennsylvania Railroad Station of Spruce Creek, Huntingdon County, Pa., at the base of the Tussey Mountain, is a great talus of broken (sandstone ?) rock. It is some 150 meters long and 30 meters high. At the base of this talus are some small pits which are said to have been dug by farmers and which act as natural ice-houses. In these pits, on the 5th of October last, I could see my breath distinctly, and on the talus the air was much colder than anywhere around it. I thought I saw ice far in among the rocks, but I could not be sure. There must surely have been some, however, for the temperature was abnormally cold.

Freezing wells are a form of natural refrigerator not uncommon in the Eastern United States. One of these was said to be at Owego, N. Y. I visited the place on the 23d of last June, and found that the well had existed, but that it had been blocked up many years ago. Mr. Preston, who had lived beside the well all his life, informed me that he had more than once been down in it, that it passed first through a layer of sand, then through a layer of gravel, and that he had seen the sides covered with ice, and that ice had sometimes filled it solid about half-way up.

At Brandon, Vt., is another freezing well. This has been described in the *Geology of Vermont* as containing ice as late as July. The owner of the well assured me that it froze solid every winter. I was there on the 7th of July, and twice lowered a thermometer, and each time, after ten minutes, it registered only 13° C., a strictly normal temperature.

At Decorah, Ia., also, there is a well which is reported as freezing up every winter. At the end of September there was no ice in it.

I wish now to make a brief résumé of the chief points which these ice deposits, and a certain number which I saw in Europe in 1897, have suggested to me, since I delivered a lecture on "Ice Caves" before the Franklin Institute two years ago.*

Natural refrigerators fall under something like five main heads:

(1) Gullies and troughs where ice remains.

(2) Boulder taluses containing ice.

(3) Ice sheets overlaid by soil or rocks.

(4) Wells, mines and tunnels which freeze at times.

(5) Caves with abnormally low temperatures and mostly containing ice.

For four of these five different rock formations, as far as they are connected with ice, we have only two terms in

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**Journal of the Franklin Institute* (1897), 143, 161-178.

English and those the entirely incorrect ones of "ice cave" and "ice gorge," and the more I have followed up the subject, the more do those names seem misnomers to me. We say "limestone cave" or "lava cave" and in the same way we should say "ice cave" when the sides and roof of a cave are formed of ice; that is, we should reserve the term for the hollows at the ends of glaciers whence the glacier waters make their exit. Curiously enough, the Germans use the same inaccurate phraseology as ourselves, and there is only one term which is really generic, namely, the French *glacière naturelle.* This is comprehensive and accurate, embracing the geological structure and suggesting the mode of formation of the ice. In my opinion we should either adopt the French *glacière* or use its English equivalent, "natural refrigerator."

The next point I wish to touch on, relates to the mode of formation of the ice of these glacières. In every case glacières seem to me to be purely refrigerators, which preserve the supplies of ice and snow stored in them during the winter. They all follow the same general laws as to their origin, modified only in slight degree according to the varying natural conditions of the place, such as the water-supply, or the protection from sun or wind, or the thickness of the overhead rocks, or the altitude or latitude. I cannot see that there is anything very remarkable about the fact that the cold of winter is able to penetrate and make itself felt sometimes for a very slight depth in the earth's crust, a depth so far as yet known never exceeding 150 meters. And it seems to me, that glacières only emphasize a law of nature which has doubtless been formulated many times in connection with springs and phreatic waters, and that is, that where we find very cold waters underground, we may be sure that they have penetrated from the outside.

The excessively hot summer of 1898 has furnished some valuable proofs of the fact that the cold of winter is the originator of the ice, and the heat of summer its destroyer. At Rumney, for instance, where there is generally ice in August, there was none last year. At Ellenville, I was told there was always ice in the cave. Yet I found none, and the temperature was normal, and as far as I could learn this was something never known before.

The fact that there was no ice last summer at the freezing wells of Brandon or Decorah, is a proof that natural refrigerators have nothing to do with a glacial period. This point was settled about caves long ago, but it might have been claimed to hold about freezing wells, as we cannot be sure how long a time the gravel beds they are dug in had been frozen. But freezing wells evidently do not depart materially in their actions from other glacières, since there was no ice at the freezing wells of Brandon or Decorah last summer, and the testimony shows conclusively that there was plenty of it last winter and that there will be plenty this winter. Any lingering doubts I may have had about the capillary theory—that is, of the ice forming by pressure—have been dispelled by visiting the cave at Decorah, where there were none of the supposed hair fissures, and which is not especially different from similar caves in Europe. If, as is sometimes claimed, the ice is formed by evaporation or by expansion of the air, and that these factors are most active when the weather is hottest, then the past summer afforded the best possible conditions for their demonstration, and there should have been ice at Ellenville and Decorah.

The subject of evaporation is closely connected with a very important point about glacières, and that is subterranean draughts and the movements of air. Believing, as I do, that it is the cold air of winter which causes the ice, it is necessary to consider its action. First, there is a form of subterranean hollow, where there are at least two openings, of which one is higher than the other. In these there are almost always draughts whose direction varies according to the outside temperature. When the air within is colder than that of the air outside, then by its own weight the air within the cave flows out at the lower opening. When, on the contrary, the air within is warmer than the air outside, then this warmer inside air rises and leaves the cave at the upper opening, and is, of course, replaced by an equal volume of cold outside air flowing in at the lower opening. This is the phenomenon of blowing caves or windholes, and when ice is found in them, it is always at the lower end, as it is at that end that the cold air enters, and it is also to that end that water gravitates. Instead of the ice in these windholes being formed by evaporation, it seems to me that when the air flows out at the lower end, it must then have a tendency to vaporize the ice and carry it away as moisture.

Then there is a class of caves where there is only one entrance and where the body of the cave is lower than the entrance. In these the air in summer is apparently stagnant, and hence they have been called static caves. The name is not descriptive, however, for in cold weather the heavy winter air sinks into these caves and displaces the air within, of course setting up some motion. Even in summer I question whether the air is always as stagnant as it seems. At the Glacière de Saint-Georges, in the Swiss Jura, there is the entrance to the cave, and at one end of the cave there is an opening in the roof. In August, 1897, the air seemed perfectly still within the cave on the ice floor, yet standing nearly under the hole in the roof, I found that the smoke of my cigar rose very rapidly straight up; it seemed almost to be drawn or sucked up from above, and certainly the air was not stagnant at that spot. There can be no question, it seems to me, that it is the movement of the heavy cold air of winter downward into these caves which supplies the cold which forms the ice in them.

Although I disbelieve that the evaporation in windholes is ever strong enough to cause ice to form, yet I have no doubt whatever, that in caves with a temperature some degrees above freezing-point, when there is either running water or strong drips, evaporation may be, and sometimes undoubtedly is, a factor in lowering the temperature somewhat; * and as in some windholes there is sometimes moisture on the rock surfaces where the air current passes,

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* This is also the opinion of M. E. A. Martel. *Les Abimes*, Paris, 1894, p. 564, and *Mémoires de la Société de Spéléologie*, 1897.

the evaporation from these surfaces doubtless sometimes lowers the temperature of the air currents appreciably.*

There is, however, no reason to think that evaporation ever lowers the temperature of air currents below freezing-point. Taking all the facts which I have myself observed, and all that I have read in the reports of others, my conclusion is that we have absolutely no proof that underground evaporation is ever effective in producing ice.

A good deal of confusion has been occasioned by the nomenclature of these caves. One kind has been termed *windröhren*, or windholes or blowing caves; the other, *eishöhlen*, or ice caves or static caves. The important point, however, in this connection is that sometimes ice occurs in both these classes of caves and sometimes it does not. I wish to repeat that the only rational terminology is the French one, to speak of any place where there is ice underground as a glacière or refrigerator. If there are two openings at different altitudes, and hence distinct draughts, then we have a windhole or blowing cave, quite independent of whether there is or is not any ice.

Another scarcely noticed point about natural refrigerators is their relation to life. Apropos of this is the following statement about the talus at Ausable Pond. This is directly on the shores of the lake, and it is known among the Adirondack guides that in front of the talus is the best spot in the whole lake to catch trout. Of course this is because the water of the lake is coldest at that spot, and trout always seek the coldest water. In the literature about glacières, however, I have found reference to an insect, *stenophylax hieroglyphicus*.† This has been found in three caves situated a long distance apart in the French Alps. Although this single case can scarcely be considered as establishing a special glacière fauna, yet the subject is worth further investigation.

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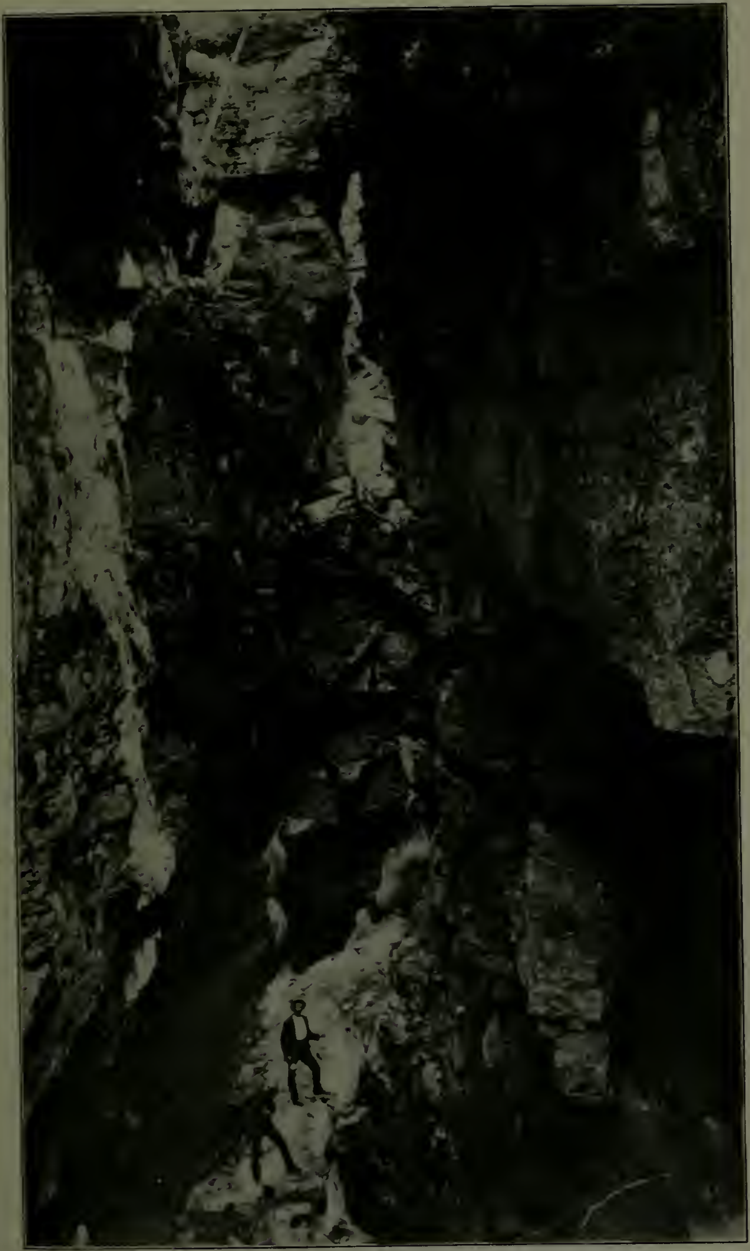
* Further observation on this point will be necessary. The cave at Farrandsville and the talus at Spruce Creek seem to me to offer unusually good opportunities for study.

† G. F. Browne, *Ice Caves in France and Switzerland*, London, Longmans, 1865; and the same in *Good Words*, Edinburgh, November, 1866.



GORGE AT ELLENVILLE, N. Y. (Photo. by Mr. Davis.)

There is more to be said in regard to plant life than to animal life. My guide to the Randolph Ice Gulch told me that he had been assured that Alpine plants similar to those found on Mounts Washington and Adams were found in the Gulch, but that they were not found on the neighboring Crescent and Bald Mountains. On the talus at Spruce Creek, it seemed to me that the flora was somewhat different from that immediately surrounding it. While at the talus at Ausable Pond, Mr. Howell called my attention to the flowers of the bunchberry and also to *oxalis*, a pretty white flower. These were in full bloom, although they were at least two weeks later than they were on the surrounding mountains. Here, therefore, is a case where the cold air coming from the rock crevices affects the flora in the vicinity sufficiently to retard its development.

THE PROBLEM OF THE MISSISSIPPI.

By Herman Haupt, C. E., Washington, D. C.

In May, 1897, the writer published several articles in the *New York Sun* on the Mississippi River problem, the aim of which was to show that of the systems proposed, neither the levee, the outlet, the reservoir, nor any other, singly, would secure protection from overflow, but that a combination of several and an intelligent application of certain recognized principles, with a careful study of local conditions was essential to a practical solution of the problem presented.

Since that time an exceedingly valuable paper has been given to the public by Mr. William Starling, Chief Engineer of the Lower Yazoo District in Mississippi, giving details not in possession of the writer at the time of the publication of the article referred to.

There has been much controversy as to the effect of levees in causing elevation of the beds of streams and very positive assertions have been made on both sides.

The statement was made by Prony that "the Po and the

Adige and almost all of their tributaries are now confined between high artificial banks and although a much larger portion of foreign matter is carried to the sea, yet a part of the sand and mud which formerly was deposited on the plains, now subsides in the bottom of the river channel and it becomes necessary, in order to prevent inundation in the following spring, to extract matter from the bed and add it to the banks. It is sometimes necessary to give an additional height of 1 foot to the banks of the Adige and Po in a single season."

In his "Principles of Geology" (Eleventh Edition, Vol. I, page 420), Lyell also states that the level of the Po has been raised by deposits.

Geike, in "Text Book on Geology," page 394, states that "between Mantua and Modena the Po is said to have raised its bed more than 5½ meters (18 feet) since the fifteenth century." Mantua and Modena are on tributaries on opposite sides of the Po, but the bottom of these tributaries could not have been raised without raising the Po also.

Mr. George P. Marsh, in a work published in 1877, says that the bed of the Po has been somewhat elevated by the deposits in the channel, though not so much as has been often represented.

Lombardini is quoted as asserting that the rate of elevation of the bed of the Po has been much exaggerated by early writers and the same is true of the bed of the Rhone and other important rivers while, on the other hand, the beds of the Adige and the Brenta are raised considerably above the level of the adjacent fields.

It appears to be very clear from these quotations that no proper conclusion can be reached in regard to the effect of levees in raising the beds of streams without taking into consideration the local conditions.

To understand this subject, it is necessary to refer to fundamental principles.

The transporting power of water depends upon its velocity. When the sectional area of a stream is contracted, the velocity, to discharge a given volume of water in a given time, must be increased, and when the area is enlarged, it will be diminished.

In a silt-bearing stream any diminution of velocity must cause deposits, and any increase of velocity from contraction of sectional area, or increase of slope, must suspend deposits entirely and sometimes produce a scour. It is possible, therefore, that one writer may assert that the bed of a certain stream may have been raised by deposits, and another deny the fact, and both may be correct in consequence of observations made at different localities.

In the case of the Mississippi River, it is well-known that an immense quantity of sediment is, in times of flood, carried by the stream. The whole area of country from Cairo to the Gulf of Mexico, a distance of 1,100 miles, constitutes a vast alluvial deposit, which is still rapidly extending by encroachment upon the Gulf.

By these deposits not only has the bed of the stream at Cairo been raised more than 300 feet, but also all the adjacent country, to the extent of many thousand square miles.

When the stream overflows its banks, the heavier particles are first deposited and the lighter carried to a greater distance, in consequence of which there are ridges of coarse material on each side of the stream 12 to 15 feet higher than the country farther back, which slopes gradually to the distant foot-hills.

Continuous levees on both sides would prevent these overflows and would confine deposits when made to the bed of the river or to the delta at its mouth.

If the river were straight, or nearly so, the levees parallel and the slopes uniform so as to maintain a constant velocity in the stream from Cairo to the Gulf, there would be no deposits in the bed, except where the velocity became reduced below that of the tributaries on the upper portion of the main river. All the sediment would then be carried to the Gulf, and would form deposits with unprecedented rapidity, but these conditions do not exist. The fall of the stream is said to be 5 inches per mile from Cairo to Memphis; 4 inches from Memphis to Vicksburg; 3½ inches from Vicksburg to Red River; 2 inches from the mouth of Red River to New Orleans; and 1 inch from New Orleans to the Gulf.

These variations of slope would necessarily produce variations of velocity, and unless the sediment had been previously deposited every reduction in velocity would cause new deposits in the bed, and every increase in velocity from contraction of the cross section by levees or otherwise would suspend such deposits, or, in some cases, might even depress the bottom by producing a scour.

As there are variations of slope and constant contraction and expansion of sectional area, there must necessarily be frequent changes of velocity, and, as a matter of course, there will be deposits in some portions of the bed and none in others, with occasional scour tending to the formation of holes.

This opinion derives confirmation from a valuable paper by Prof. J. B. Johnson, read before the American Association for the Advancement of Science, in 1884, in which this language is used:

"It would seem, therefore, that in the river's present condition, there is no evidence that a confined flood will scour out its bed so as to facilitate the discharge, and there is considerable evidence against it. If the river flowed between straight parallel banks, such as Captain Eads has constructed at the mouth of the river, there then could be no such thing as discontinuous transportation of sediment, and hence no alternate scour and fill. Then concentration of volume would be beneficial and would ultimately lower the river bed. But this condition of things can never be reached on the Mississippi River, and hence the concentration of flood volume will be harmful rather than beneficial."

EFFECT OF CONTINUOUS LEVEES.

To form an opinion as to the increased height of floods that will result from the construction of strong continuous levees, it is necessary to know, at least approximately, the additional volume of water that in extreme floods may be thrown into the main river.

It is stated by William Starling that if all the tributaries of the Mississippi were in flood at the same time the discharge would reach 3,000,000 cubic feet per second.

The flood of 1897 proceeded mostly from the Ohio, and the discharge at Cairo was 1,570,000 cubic feet per second, and below the mouth of the Arkansas, 1,740,000 cubic feet per second.

Others have estimated maximum floods at 2,000,000 cubic feet per second, of which only 1,000,000 cubic feet reached the mouth of the river; the remainder covered and formed deposits in the swamps and found its way by outlets and cut-offs to the Gulf.

Below Cairo and above Helena and Vicksburg there are the two great basins of the St. Francis and the Yazoo.

The basin of the St. Francis contains 6,706 square miles and the basin of the Yazoo 6,648 square miles.

There are also several other extensive basins which are important factors in any attempt to solve the problem of the Mississippi. These are:

The White River Basin, embracing 956 square miles.

The Tensas Basin, 5,370 square miles.

The Atchafalaya Basin, 8,109 square miles.

The Pontchartrain Basin, 2,001 square miles.

The aggregate of these basins is 29,790 square miles.

Each basin is bounded by a ridge and drained by a river, which usually flows near the base of the ridge.

The great alluvial bottom of the St. Francis is 190 miles long and 35 miles wide, bounded by Crowley's Ridge, which abuts upon the river at Helena. This ridge has no gaps, and is said to be far above the highest water of the Mississippi.

The elevation and width of this ridge might possibly render it impossible, at any reasonable cost, to provide a cut-off to discharge a portion of the surplus water in high floods into the lower valleys and prevent their return to the main river. If this be the case, the overflow into the St. Francis basin must be discharged into the river at Helena, and add to the height of the flood, but the reservoir still will have a very beneficial effect in delaying the arrival of the crest of the wave at Helena from six to eighteen days. The outpour from the St. Francis produces a rise at Helena of 1 foot per day for three or four days. If the St. Francis and Yazoo basins were closed entirely by levees, the height of the flood would be greatly increased. Starling remarks: "The closure of the upper basins will have the undesirable effect of bringing the floods from the upper river into closer coincidence with those from the White and Arkansas, and this may justly be considered a serious element of danger."

Starling estimates that the closure of the St. Francis and White River basins will raise the crest of the flood at Helena 5 feet.

"The St. Francis was closed since 1893 to a distance measured along the river of 120 miles and a gap of 100 miles still remains. It is to the building of these levees and to the maintenance of the lines previously existing that the unparalleled stages attained by the water has been due."

It is also stated by the same writer that the gauge at Sunflower would undoubtedly have stood 7 feet or more above all previous records if crevasses had not occurred in the levees in front of the White River basin and the levees would have been deeply submerged if something had not given way.

If the partial closing of the levees in front of some of the basins has resulted in such an enormous increase of flood height that the most elevated levees would have been overtopped and submerged but for the relief afforded by crevasses, what result may be expected when the whole river is confined by continuous levees on both sides? If the volume of water that is poured into the upper portion of the Mississippi is twice as great as is now discharged at its mouth, what must be the elevation of the crest lines of the flood when the volume is doubled? The idea that an increase of velocity will result from the increased volume and, that in consequence, a scour will be produced that will increase depth sufficiently to compensate for increased height of flood has been shown to be fallacious. If there was a continuous scour the material must be deposited somewhere, and the only conceivable place of deposit would then be at the Gulf. reinforced by all the material brought in from the tributaries and from erosion of the banks, in which case the amount would be so enormous that it would be almost impossible to maintain navigation and New Orleans might become an inland city. Heretofore, relief has been afforded by crevasses and cut-offs by which it is said that half the volume in flood stages has found its way to the Gulf through swamps, bayoux and secondary streams, and was not discharged through the passes. When these avenues of escape are cut off there must necessarily be a great increase in the flood height unless some other mode of relief can be provided.

CAN RELIEF BE AFFORDED BY RESERVOIRS?

At the St. Francis basin in the natural condition of the river the water begins to escape from the Mississippi and run over its banks at a stage of about 39 feet on the Cairo gauge or 40 feet at Helena, and the volume diverted is 300,000 cubic feet per second or more. This overflow consumed seventeen days in 1890 and twenty-three days in 1891 in reaching Helena. The extreme high water in Cairo has been 51·83 feet. The highest point reached at Helena since 1870 was almost exactly the same or 51·85 feet. The ordinary level at Cairo has been given at 294·71 above mean tide, and at Helena 165·00. The difference is 129·71 feet and if the direct distance be taken at 190 miles the general slope of the basin would be 8 inches per mile.

To convert the basin of the St. Francis into a great reservoir or lake of 6,706 square miles capacity with slack water throughout its whole extent, the level of the surface must be 346·54 feet above tide, and the height of a dam and levees at Helena would be required to be 182 feet. If it be assumed that the surface of this reservoir in consequence of a discharge at its lower end should have the same fall as that of the river or 5 inches to the mile, the height of the structure at Helena to retain it must be over 100 feet.

To convert the basin into a reservoir to hold back the floods would destroy the agricultural lands, which are said to be valuable.

If the basin of the St. Francis should be leveed throughout its whole extent and the mouth of the river alone left open, the backwater would extend from low-water line 78 miles, and to protect the arable lands in this portion of the basin the banks of the St. Francis must also be leveed.

The idea of converting the basins of the Mississippi into reservoirs to hold back the floods must be abandoned as impracticable, as similar difficulties would be presented in the other localities.

THE OUTLET SYSTEM.

The advocates of the outlet system claim the ability to reduce the height of the floods and prevent overflow by providing outlets to secure a more rapid discharge of the water in time of flood by a more direct channel to the Gulf.

It is stated that a crevasse at Bonnet Carre, a short distance above New Orleans, which discharged one-twelfth of the flood water through Lake Pontchartrain, in going 6 miles instead of 160 miles to the river's mouth, lowered the high-water mark at New Orleans from 3 to 4 feet, where the rise and fall was 17 feet, and lowered it at Natchez, 300 miles above, from 6 to 8 feet, where the rise and fall was 50 feet.

It is also claimed that an outlet 1 mile wide by 10 to 12 feet deep, with a fall of 12 feet in going 6 miles to Lake Borgne, would divert one-twelfth more of the discharge and reduce the high-water level at New Orleans in all 8 or 10 feet, and at Natchez, from 14 to 15. Whether these published statements be accepted as reliable or not there can be no question that outlets will reduce the height of floods if properly located and of sufficient number and size. In fact, nature provides them for its own relief, by means of the crevasses, which afford protection to localities many miles distant. It would seem, therefore, that permanent outlets properly located might afford permanent relief. Objection is made that the change in the velocity of the current below the crevasses causes the formation of bars and results in an impediment to low-water navigation.

The most serious objection to the outlet system is that while it might afford relief in high water, it would cause evils in low stages by diverting water required for navigation.

It would not be difficult by means of an outlet of sufficient size to turn the bulk of the waters of the Mississippi into the Atchafalaya, which would give a shorter distance to the Gulf, a steeper slope, and a more rapid discharge.

What is needed is to maintain in the Mississippi the depth for navigation, and discharge the excess as rapidly as possible, which requires that the plan adopted should not permit a discharge at too low a level.

CONTRACTION.

Contraction is a local remedy to produce a scour for the removal of bars and deepening of navigation. It consists in reducing the cross-section and thereby increasing the velocity at certain points. In some cases it may be expedient to resort to dredging to secure a channel that can afterward be readily maintained in low water by a contraction of the cross-section. It is in general easier to maintain a channel than to create it by means of scour. Contraction is one of the auxiliary means to which the engineers must resort in special cases. It is not applicable to continuous improvement.

REVETMENTS

A river flowing through an alluvial plain has a constant tendency to change its course and produce a series of horseshoe curves. The constant erosion gradually reduces the distance across at the heel of the shoe, and at length a high flood breaks over and cuts away the intervening neck of land and creates a new channel, leaving in place of the old channel a bayou often many miles in extent.

This action often menaces important cities such as Vicksburg and Memphis, and renders necessary protection against the eroding action of the stream.

It is also an object of great importance in the interest of navigation that the bank of the stream should be protected from this erosive action, since the vast amount of material removed must be redeposited at other points in the bed of the stream, forming serious obstruction to navigation.

The protection of the banks by revetments is therefore an object of importance, and the benefit to be derived therefrom is not merely local, but general. It concerns, however, the question of navigation rather than the protection of plantations from overflow.

A POSSIBLE SOLUTION OF THE PROBLEM.

The objects sought are twofold—to maintain a navigable channel in the Mississippi in low water, and to prevent the destruction of life and property by floods.

The evidence presented should be conclusive that parallel levees of any ordinary height, continuous on both sides of the streams, with outlets all closed, compelling the river to carry and discharge into the Gulf double the former volume of flood water will not, with certainty, secure the country permanently against overflow, but when the limit of the capacity for protection has been attained the danger from crevasses, if they should occur, will be vastly increased.

It may be that careful unbiased examination will lead to the conviction that the continuous levee system, bad as it is, is, nevertheless, the only one practicable, and that whatever may be the height to which levees must be raised, the expense must be incurred to avoid evils of greater magnitude, but this conclusion should not be reached without the most thorough investigation.

THE WASTE WIER SYSTEM.

There is one system which holds out a promise of more satisfactory results than any other, and which has not, so far as known to the writer, formed the subject of any extended discussion, and that is a system of *waste wiers*, to discharge the excess above a safe level in extreme floods without reducing the volume required for the navigable stages.

Every canal engineer understands that in constructing a summit level to supply lockage for his canal, he must provide what are called waste wiers, so that when floods fill the feeders and the canal level to a certain height, the surplus will be discharged over wiers into the natural water channels of the country, and thus prevent a rise that would endanger the banks.

By a similar arrangement, if local conditions would permit, extensive wiers might be provided at suitable points along the Mississippi which would be inoperative under ordinary conditions of the stream, but when the river reached a level, to be determined by the engineer in charge, the surplus would begin to pour over the wiers and discharge into the Gulf by the Atchafalaya and other streams.

The effect would be not only to reduce the height of the flood, but also to carry off a large amount of the sediment that would otherwise be deposited in the bed of the river or carried through the passes to form bars in the channel at its mouth, and it would also help to fill up the swamps, and thus, in time, add to the area of arable land.

As to the proper location for such wiers no decision can be reached without a careful and intelligent study of localities with special reference to the settlement of the question with all the collateral questions which it involves, but an examination of the carefully prepared maps of the U. S. Engineer Department would seem to indicate that if the elevation of Crowley's Ridge near Helena is not excessive, a cut of moderate length would throw a portion of the high water volume of the St. Francis into the headwaters of the White River, while another cut of greater length, but over ground of low elevation, would turn a large volume into the tributaries of the Atchafalaya and lead by a short cut to the Gulf. These cut-offs would be entirely dry except when the floods had reached a dangerous elevation.

The waste wiers on the west side of the river would also, by lowering the surface level of the river, afford relief on the east side, but so far as concerns the basins of the Yazoo and Big Black, no relief by a cut-off to the Pearl would appear to be practicable, as the country between these rivers is too high. It would appear to be practicable, however, to divert a portion of the high-water discharge of the Arkansas and the Red into the Atchafalaya, and thus greatly relieve the levees of the lower river.

These suggestions are made with much diffidence, as it will require a thorough examination of localities to decide the question of practicability.

QUANTITY OF DEPOSITS.

With continuous levees on both sides of the Mississippi, from Cairo to the Gulf, thus preventing any lateral deposits, the quantity of solid material carried by the stream must be enormously increased, particularly when reinforced by the erosion from the banks.

All the material must be carried to the mouth, with the exception of the portion deposited upon the bed.

It has been estimated, as previously stated, that with the tributaries in full flood at the same time as the main river, the total discharge might reach 3,000,000 cubic feet per second, but an estimate will be made on 2,000,000 as conservative during a high flood.

In 1879 Colonel Suter found the mean proportion of water to sediment at St. Charles, near the mouth of the Missouri, to be 265 to 1, but below Cairo, after dilution with the clearer water of the Ohio, the proportion was only 1,061 to 1.

On the basis of this proportion and allowing no addition for erosion of river banks, the deposit at the mouth of the Mississippi would cover, in twenty-four hours, an area of 4,050 acres, or 6⅓ square miles, to a depth of 1 foot. It is also stated that since 1838 the fill 10 miles out from the passes has been 620 feet, which at the same rate continued would carry it to the surface in eighteen years. The completion of the continuous levee system would enormously increase the volume of these deposits and necessitate great rapid and continuous extension of the jetties with constant dredging. This is an important factor to be considered in the determination of any plans for improvement.

THE FIRE UNDERWRITERS' RULES FOR SAFE INTRODUCTION OF ACETYLENE GAS GENERATORS.

Communicated, with some introductory remarks, by CHAS A. HEXAMER,
Member of the Institute.

The rapid increase in the use of Acetylene Gas as an illuminant, demonstrated to Underwriters' Associations throughout the country the necessity of rules for safe introduction of acetylene gas generating apparatus. Various associations have attempted to control such installations by adopting forms of permits and rules. These rules indicate considerable difference of opinion in regard to the fundamental question whether or not the generating apparatus, when gas is generated directly from calcium carbide, could safely be allowed in the insured building, and whether or not liquefied acetylene gas, or gas generated from same, could be used with safety under any circumstances.

In order that the question relating to the placing of the generating apparatus in an insured building could be decided, and for the purpose of preparing uniform rules for use throughout the country, the Committee on Heating, Lighting and Patents of the National Board of Fire Underwriters, issued a call for a meeting of duly authorized representatives of Underwriters' Associations, for the purpose of a conference, and, possibly, agreement on general rules for the safe use of the new illuminant. This meeting was held in New York in June, 1898, and was well attended. The question of the location of the generating apparatus in the insured building was first considered, and led to so protracted a discussion that it became apparent that it would be necessary to refer the question of general rules to a special committee. The conference having adopted a resolution providing for the location of the generating apparatus inside a building, subject to discretion of Underwriters' Associations having jurisdiction, a special committee was appointed, which, in December, 1898, unanimously reported the rules printed below.

After a careful consideration and approval of the rules by Prof. Henry Morton, of Stevens Institute, Hoboken, N. J., they were submitted by the National Board of Fire Underwriters to the various Underwriters' Associations for adoption.

In formulating the rules, it was the aim of the Committee to treat the subject as broadly as possible, and without specifically describing a standard generator to lay down fundamental principles and rules beyond which it is unsafe to go.

NATIONAL BOARD OF FIRE UNDERWRITERS.

COMMITTEE ON LIGHTING, HEATING AND PATENTS.

156 Broadway, N. Y.

ACETYLENE GAS RULES.

NEW YORK, December 27, 1898.

At the last annual meeting of the Board, the Committee on Lighting and Heating submitted proposed regulations for the installation of acetylene gas apparatus which were referred back to the Committee with instructions to call a meeting of the experts of the several Underwriting Associations in order to secure uniform rules on the subject throughout the country. That meeting was held on the 21st and 22d of June, 1898, when a careful consideration of the points at difference between the Associations led to a reference of the matter to a special committee composed of Messrs. Charles A. Hexamer, of the Middle Department Association, Philadelphia; W. A. McCutcheon, Inspector Board of Underwriters, Pittsburgh; W. C. Robinson, of "The Union," Chicago; F. M. Griswold, New York; W. B. Medlicott and Ellwood Hendrick, of the New England Exchange, Boston. That Committee held several meetings, giving the most thoughtful care and attention to the subject, and finally reported the following rules, which, having also received the approval of our scientific expert, have been duly adopted by this Committee, and are now promulgated as the Standard of the National Board of Fire Underwriters.

The Committee regrets the delay in the issue of the rules, which, however, was unavoidable, because of the differences of opinion which existed on important points, and which it was desirable to harmonize in the interest of all. It is recommended that all Associations and Boards of Fire Underwriters adopt the rules, of which action please send notice to H. K. Miller, Secretary, 156 Broadway, New York, of whom additional copies of the rules can be had.

HENRY H. HALL, Chairman, New York.
J. H. WASHBURN, New York.
JAMES NICHOLS, Hartford.
R. DALE BENSON, Philadelphia.
H. F. ATWOOD, Rochester.

NATIONAL BOARD RULES GOVERNING CONSTRUCTION OF STANDARD APPARATUS.

The use of liquid Acetylene or gas generated therefrom is absolutely prohibited.

The permission to generate and use Acetylene in insured premises shall be subject to the following rules.

APPARATUS.

It is desirable that all Acetylene Gas machines shall be installed outside of the building insured, but special permission may be granted in the discretion of tariff associations having jurisdiction to install machines inside the building under special circumstances, such permission to be given in writing and shall be subject to the following rules:

(1) Must be made of iron or steel, and in a manner and of material to insure stability and durability.

(2) Must have sufficient carbide capacity to supply the full number of burners during the maximum lighting period.

> NOTE.—This rule removes the necessity of recharging at improper hours. Burners almost invariably consume more gas than their rated capacity and carbide is not of staple purity, therefore, there should be an assurance of a sufficient quantity to last as long as light is needed. Another important feature is that in some establishments burners are called upon for a much longer period of lighting than in others, which requires a generator of greater gas-producing capacity.

(3) Must be uniform and automatically regulated in its action, producing gas only as immediate consumption demands, and so designed that gas is generated without excessive heating at all stages of the process.

> NOTE.—This rule is necessary, because the presence of excessive heat tends to change the chemical character of the gas and may even cause its ignition.

(4) Apparatus not requiring pressure regulators must be so arranged that the gas pressure cannot exceed thirty tenths inches water column (three inches).

(5) Must be provided with an escape pipe which will operate in case of the over-production of gas, and also an attachment acting as an escape or relief in case of abnormal pressure in the machine, and which will carry such excess gas through an escape pipe of at least three-quarter-inch internal diameter to a suitable point outside of building, discharging at least twelve feet above ground level and provided with an approved hood.

> NOTE.—Both the above safety vents may be connected with the same escape pipe.

(6) Apparatus requiring pressure regulator must be so arranged that the gas pressure cannot exceed three pounds to the square inch. Such apparatus must be provided with additional safety blow-off attachment located between the pressure regulator and the service pipes and discharging to the outer air, the same as provided for in Rule 5.

> NOTE.—This is intended to prevent the possibility of undue pressure of gas in the service pipe by failure of the pressure regulator.

(7) Must be so arranged that when being charged the back flow of gas from the holder will be automatically prevented, or so arranged that it is impossible to charge the apparatus without first closing the supply pipe to holder, or to other generating chambers, if any.

> NOTE.—This is intended to prevent the dangerous escape of gas.

(8) Must be so arranged as to contain the minimum amount of air when first started or recharged, and no device or attachment facilitating or permitting mixture of air with the gas, prior to consumption, except at the burners, shall be allowed.

> NOTE.—Owing to the explosive properties of acetylene mixed with air, machines should be so designed that such mixtures are impossible.

(9) No valves or pet-cocks opening into the room from gas-holding part or parts, the draining of which will allow an escape of gas, shall be permitted; and the condensation from all parts of the apparatus must be automatically removed without the use of valves or mechanical working parts.

> NOTE.—Such valves and pet-cocks are not essential; their presence increases the possibility of leakage. The automatic removal of condensation from the apparatus is essential to the safe working of the machine

(10) The water supply to generator must be so arranged that gas will be generated long enough in advance of the exhaustion of the supply already in the gas holder to allow of the using of all lights without exhausting such supply.

> NOTE.—This provides for the continuous working of the apparatus under all conditions of water feed and carbide charge, and it obviates the extinction of lights through intermittent action of the machine.

(11) No carbide chamber of over twenty-five pounds capacity shall be allowed in any machine where water is introduced in small quantities or where the contact of water with carbide is intermittent.

> NOTE.—This tends to reduce the danger of overheating, and provides for the division of the carbide charges in machines of these types of large capacity.

(12) Generator must be connected with the gas-holder in such manner that it will, at all times, give open connection either to the gas-holder or to the blow-off pipe into the outer air.

> NOTE.—This prevents dangerous pressure within or the escape of gas from generating chamber.

(13) Must be so designed that the residuum will not clog or affect the working of the machine and can conveniently be handled and removed.

(14) Covers to generators must be provided with secure fastenings to hold them properly in place, and those relying on a water seal must be submerged in at least twelve inches of water. Water seal chambers for covers depending on a water seal must be one and one-half inches wide and fifteen inches deep, excepting those depending upon the filling of the seal chambers for the generation of gas, where nine inches will be sufficient.

(15) Holder must be of sufficient capacity to contain all gas generated after all lights have been extinguished.

> NOTE.—If the holder is too small and blows off frequently after lights are extinguished there is a waste of gas. This may suggest improper working of the apparatus and encourage tampering.

(16) The bell portion must be provided with a substantial guide to its upward movement, center guide preferred, and a stop acting about one inch above the blow-off point.

> NOTE.—This tends to insure the proper action of the bell and decreases the liability of escaping gas.

(17) A space of at least three-quarters of an inch must be allowed between the sides of the tank and the bell.

(18) All water seals must be so arranged that the water level may be readily seen and maintained.

(19) Gas-holders constructed upon the gasometer principle must be so arranged that when the gas bell is filled to its maximum its lip or lower edge shall at all times be submerged in at least nine inches of water.

(20) The supply of water to the generator for generating purposes shall not be taken from the water seal of any gas-holder constructed on the gasometer principle.

NOTE.—This provides for the retention of the proper level of water in the generator.

(21) The apparatus shall be capable of withstanding fire from outside causes without falling apart or allowing the escape of gas in volume.

NOTE.—This prevents the use of joints in the apparatus relying entirely upon solder.

(22) Gage glasses, the breakage of which would allow escape of gas, shall not be permitted.

(23) Where purifiers are installed, they must conform to the general rules for the construction of other apparatus and allow the free passage of gas.

(24) The use of mercury seals is prohibited.

NOTE.—Mercury has been found unreliable as a seal in acetylene apparatus.

(25) Construction must be such that liquid seals shall not become thickened by the deposit of lime or other foreign matter.

(26) Apparatus must be constructed so that accidental syphoning of the water is impossible.

(27) Flexible tubing, swing joints, packed unions, springs, chains, pulleys, stuffing boxes and lead or fusible piping must not be used on apparatus, except where the failure of the part will not vitally affect the working or the safety of the machine.

(28) There shall be plainly marked on each machine the maximum number of lights it is designed to supply and the amount of carbide necessary for a single charge.

To be approved, Acetylene Generators must conform to the foregoing standard, and plans and specifications in detail of such apparatus must be submitted to the insurance organization having jurisdiction over the territory in which such apparatus is to be installed, for approval by an inspector duly authorized by the . . . . Association, with whom a copy of such plans and specifications must be filed. If the plans are approved, a special examination of the Generating Apparatus will be made at the expense of the applicant, and if it is found to be in compliance with the standard, a certificate of approval will be issued.

CALCIUM CARBIDE.

(1) In no case shall Calcium Carbide be stored in bulk.

(2) Calcium Carbide must be packed in screwed-top, water-tight metal packages, having all seams lock-jointed and soldered. They shall contain not over 125 pounds of Carbide, and each package must be conspicuously marked "Calcium Carbide, Keep Dry." The packages must be of sufficient strength to insure the handling of the same without rupture, and they must be kept under cover at all times.

INDORSEMENT FOR USE OF ACETYLENE GAS.

In consideration of the following warranties on the part of the assured, permission is hereby granted to generate and use Acetylene Gas on the premises described in this policy, using a . . . . Acetylene Gas Machine, manufactured by . . . . at . . . . when the same is installed in accordance with the rules and regulations of the National Board of Fire Underwriters, and adopted and promulgated by the . . . . Association.

WARRANTED.

That the Generator shall be charged, and Calcium Carbide handled by daylight only;

That no direct fireheat or artificial light shall be allowed in the room containing the apparatus;

That no Calcium Carbide shall be kept in the building where this policy covers;

That no greater number of lights shall be installed than the maximum for which the machine is rated;

That no change shall be made in the installation without the written consent of this company indorsed hereon.

Attached to and made a part of Policy No. . . . . of the . . . . Insurance Company, of . . . .

. . . .

The use of Liquid Acetylene, or Gas generated therefrom, on the premises described herein is absolutely prohibited.

CAUTIONS.

Calcium Carbide should be kept in water-tight metal cans, by itself, outside of any insured building, under lock and key, and where it is *not* exposed to the weather.

A regular time should be set aside for attending to and charging the apparatus during *daylight* hours only.

In charging generating chambers, clean all residuum carefully from the containers and remove it at once from the building. Separate the unexhausted Carbide, if any, from the mass and return it to the container, adding new Carbide as required. Be careful never to fill container *over* half full, as it is important to allow for the swelling of Carbide when it comes in contact with the water.

Never place Carbide into the containers until all residuum has been carefully removed.

Water tanks and water seals must always be kept filled with clean water.

Where apparatus is not intended for use throughout the year, all water must be removed at the end of season.

Never use a lighted match, lamp, candle or any open light near the machine.

ELECTRICAL SECTION.

"Railroad" Meeting, March 28, 1899.

SOME OF THE LARGER TRANSPORTATION PROBLEMS IN CITIES.

BY EDWARD E. HIGGINS.

The managers of a large city railway system are constantly called upon to deal with problems of great difficulty and complexity. They have a double responsibility—a responsibility to the public and a responsibility to the investors of whose interests they are trustees. They are charged with the management of thousands of employés, whose attitude toward the enterprise, whether of content or discontent, is of vital importance to its success. They must pass upon inventions and improvements in the science of municipal transportation, determining where cost and true economy join hands; they must adopt operating methods adequate to the development of the system and of the city which it serves; they must care for the comfort and pleasure of the public; and they must so unify all of these varied and sometimes conflicting duties as to develop an organization and management successful as a whole and not unduly weak in any part.

Grave misunderstandings often arise between street railway companies and the public. The people often believe the companies to be grasping, sordid, careless of their duties as public carriers and desirous only of making the largest possible return to stockholders. The companies, on the other hand, daily harassed by complaints about inconveniences suffered, small or large, often came to regard the public as unreasonable in its demands, forgetting that that public is not in a position to see all the difficulties and perplexities which beset the management at every turn, and which make it often either impossible to grant such demands or to explain why they cannot be granted. The street railway business, as a whole, is so complicated and so much a matter of detail, that no one department of it can be well understood without some knowledge of the others, and fragmentary or partial explanations of the reasons for specific decisions, however sound in their relationship to the general plan of management, might not always or often appear so to non-technical critics.

I shall attempt in the following discussion to give such an explanation of the entire scheme of modern street railroading on its broad lines and of the principal problems which the manager has to solve, as will lead to a clearer understanding, by those who are not of "the faith," of what the public has a right to expect from the street railway companies, which are its servants and which are, as a rule, honestly trying to fulfil all the obligations which can reasonably be imposed upon them.

ESSENTIAL DIFFERENCES BETWEEN CITIES.

In the first place it cannot be too clearly made evident how different are the transportation conditions in each city from those of any or all other cities. Nothing can be more fallacious, or lead to greater injustice, than to say that because such and such concessions are granted by the companies to the people of a certain city, therefore, similar ones can and should be made in another city. The most common error of all perhaps is to assume that the conditions found in a small city obtain in a large one or *vice versa*. Population and population density have an enormous influence on street railway earnings, profits and possibilities of generosity. A second even more common error is to hold that as much ought to be expected from an old company which has passed through one or more experimental stages of street railroading and had to throw away enormous investments for antiquated motive powers and to purchase their substitutes at high initial prices, as from a new company just entering the field, with all the accumulated experience of many years to draw upon, and with the benefit of low prices for material and supplies of the present day. Behind these more obvious injustices come others less easy to understand without some technical exposition. How, for example, can a manager satisfactorily explain to the public the reason why the people of his city patronize their street railway system to the extent of only $3 per capita per annum, while in another city of the same population, the earnings are over $5 per capita? When the generosity of the richer system is cited as a precedent for the poorer to follow, it is a delicate matter to show that the latter's public is largely composed of the working classes to whom the daily 5- or 10-cent fare forms a material burden, or a difficult one to make clear that the plans on which the two cities are laid out are radically different, the one calling for greater patronage of street car lines than the other, without necessarily involving greater expense to the operating company. A knowledge of these differences in city plans and lines of development is so essential to the understanding of the theory of street railroading that a brief explanation of their effect upon earnings is desirable.

The world's great cities are, with scarcely an exception, built upon or around some form of water front—sea, lake or river. Upon some section of this water front is always found the "congested district," devoted to commercial and business purposes. The manufacturing districts of a city may or may not be on this water front, according to the location of the railroad termini and branches, the presence or absence of rivers tributary to the main water front, and other governing conditions. All, or nearly all cities are laid out and developed on one of four distinctive plans, (1) the peninsula plan, such as that of New York City (Manhattan Borough) and San Francisco; (2) the valley plan, with a river or rivers running through the center, such as Pittsburgh; (3) the radiating plan, with territory on one side only of water front, such as Chicago, Boston, Brooklyn and many other cities; and (4) the radiating plan, with territory on both sides of the water front, of which examples are found in Metropolitan New York (including Eastern New Jersey), Paris, London and many other cities, large and small.

The peninsula and valley plans usually call for comparatively small street railway track mileage, and great traffic density is found on that mileage, together with large gross earnings per capita served, per mile of track and per car mile. For example, the complete transportation system of New York City proper (Boroughs of Manhattan and the Bronx) earns about $13 per capita gross, and that of San Francisco nearly $14. The radiating plans mean greater street railway mileage for the population served, and usually a much less density of traffic and less gross receipts per capita. The Chicago surface and elevated lines, for example, earn less than $10 per capita, and the surface lines of St. Louis hardly $8 per capita.

It can be easily seen how different, for example, is the transfer problem in a peninsula and valley city from that of a radiating city. In the former there may be a few through lines of heavy traffic, with many cross-town feeder lines. Transfers in such a city might mean no additional expense to a company and little or no complication. In the radiating city, on the contrary, a transfer system might mean a ride of great length, while the plan of the system might be such that dishonesty in the use of transfers would be easily possible.

Again, a city plan very favorable to economical operation might make a 4-cent fare possible in a given city, while in another city, even of the same population, such a fare would mean bankruptcy. A city system of large track mileage running many cars might have immense maintenance accounts to deduct from earnings, whereas, a more fortunate one in another city would have a great traffic density on small mileage. All that a comparison of practice between the street railway systems of two cities can do, therefore, is to put the burden of proof upon the system which is apparently less generous with the public of showing why the more generous practice cannot be followed, and the company's argument should be received with attention and respect, for after all, nothing is more certain than that the best reasonable service of the public will bring about the largest earning power to a street railway company, and none is more quick to recognize this fact than the average street railway manager.

THE FUNCTION OF ELEVATED AND UNDERGROUND RAILWAYS IN CITY TRANSPORTATION SYSTEMS.

The question of adding to existing facilities or solving different congested district problems by the building of elevated or underground railways is facing the managers of several of the principal cities of the world, and it is a serious one indeed. The enormous cost of tunneling, and the hardly smaller combined investment required for building an elevated structure,and paying damage claims to abutting property owners, leads and will lead to a postponement of the issue as long as possible. The great tunnels of Paris are an immense burden upon French taxpayers, while private capital cannot hope to make a success of tunnel enterprises except in countries where rates of interest are extremely low, and even then the public must usually be called upon to help by special concessions or subsidies of one kind and another. The London Metropolitan underground system is a failure financially, partly because of its immense cost and partly because it was not properly laid out to obtain the greatest density of traffic. It is hoped that the new Central London Underground will be more successful, being comparatively short and built under one of the heaviest traffic routes of that great city. Private capital has so far shown very little enthusiasm for an underground railway in New York City, where, if anywhere in America, such a railroad should prove profitable.

The elevated railway system of Manhattan Island has been in the past exceedingly profitable, chiefly because it is built in a "peninsula city" *par excellence*, where an immense tide of travel sweeps south in the morning and north at night, along few and narrow lines, but the fact that through all these years until the present time the New York elevated lines have had as competitors only comparatively slow-moving horse cars, has been almost equally potent in effecting profits, since short-distance as well as long-distance travelers have been obliged to use the elevated when time is an object. Elevated railroading in the two "radiating cities" of Brooklyn and Chicago has been distinctly unprofitable. In cities of this class it is difficult or impossible to find the density of traffic necessary for the payment of operating expenses and interest upon the heavy capital outlay required. This is particularly true where the surface cars are run at frequent intervals and at high speeds, for the latter will inevitably obtain the short-distance or more profitable class of traffic, leaving the long-distance or unprofitable class only to the elevated lines. Moreover, in cities of the radiating class, the population is usually spread out over so large an area as to make it impossible for any one line to obtain a large proportion of the traffic. The adoption of electricity on the elevated lines in Chicago has favorably affected gross and net earnings, and with the scaling down of capitalization, which has recently been accomplished, there is a possibility that a reasonable return on the new capitalization can be made if new competitive conditions do not arise; a similar result is hoped for in Brooklyn. It is by no means improbable, however, that the only permanent solution to the problem of running surface, elevated and underground railways in the same city is to have them under one control and management, so that the surface lines can serve as feeders to the elevated or underground lines, an express service only to be given on the latter, and a fare charged for the combined service somewhat greater than the single 5-cent fare.

In the congested districts of our principal cities, elevated or underground lines, either or both, will find a true and valuable field. The business sections of Chicago and Boston furnish problems of the most serious and complicated character, which are only partially solved at present, and are likely to grow graver in geometrical ratio as the years go on, and as the territory tributary to the business centers increases in area and population. It is probable that the only permanent solution to congested district problems in cities lies in subway or tunnel lines and loops in these districts. These will take from the surface of the streets the enormous crowds of people which at morning and evening hours of the day pour into and out of the tall buildings which have become so necessary an evil in the modern city business districts. Boston's new subway is a decided, though not as yet a complete, success in relieving congestion and saving time throughout a large portion of the twenty-four hours. The new Boston elevated lines at present under construction will be of great assistance in this congested district, passing as they do from its limits on the north and west (the latter projected) to those on the south, and the managers of the great city railway property in Boston have done wisely in confining these elevated lines to the congested district and not carrying them to a greater distance away from the business center. In Chicago, the Loop Terminal of all the elevated lines, recently put into operation, has been a great convenience to the people, and has added largely to the traffic, but it is a question if it has not even so soon reached its train capacity, particularly on days of its heaviest traffic; for on a recent holiday, no less than 65 per cent. of the trackage on one of the loop lines of the structure was covered by trains, *i. e.*, they were less than a train length apart on an average.

THE PROBLEM OF MOTIVE POWER.

No decisions which street railway managers have been called upon to make during the past ten years have caused them such anxious solicitude, and have meant so much to the public and to stockholders as those connected with motive power. Ten years ago horse traction was almost universal, with the cable in use or building on the heavy traffic routes of a few cities, and electricity just coming into sight. To-day electricity reigns triumphant, having displaced both horses and cable on nearly all the mileage of American cities. A synopsis of the reasons for this wonderful revolution in transportation methods which has completely changed the complexion of our cities, and added new life and vigor to their daily routine, will be of present as well as retrospective interest, inasmuch as the primacy of electricity, and particularly of overhead wire electric traction is still occasionally disputed.

All motive powers may be divided into two classes, those which make a car a more or less independent unit on the streets, and those which make it constantly dependent on some central source of power. To the first class belong the horse car, the storage-battery electric car, the compressed-air car, and various forms of gas, stored steam, petroleum and other motor cars. To the latter belong the cable system and the electric overhead wire and conduit systems.

Independence in the car unit is a highly desirable thing. With it comes minimum disturbance of the pavement or obstruction in the streets with minimum investment for installation; and with it comes also an avoidance of the danger that the central source of power may give out and stop the entire system, or any large section of it for a considerable period. There is no question that a really successful independent unit system would be heartily welcomed by street railway managers, certainly as an auxiliary, and would find a large field immediately ready for occupancy.

But there are serious obstacles to success. It is probably impossible to devise a power generating and using system which will go within the narrow space limits available in a modern popular car, and which shall be capable of exerting as a maximum a power four or five times the average amount required for the propulsion of the car. Such a system can be placed in a dummy car and some room left for passengers as well, but while one or more trail cars are to be drawn, difficulties of traction come up immediately. At all times there is the impossibility of generating power in small amounts with anything like the economy with which it can be generated in large. If power be generated in quantities at some central station and stored in some one of several forms for transfer to, and use on a car, that car, is quite as surely dependent on the central station as it would be were the power transmitted by wires or cable, and is likely to give even more trouble through the exhaustion of the stored power and the consequent stoppage of the car on the line. Still another difficulty is found with so-called independent car operation (except where electric motors are used as in the storage-battery system), and that is the impossibility of producing a rotary motion without the use of an initial reciprocating motion, with all the latter's well-known disadvantages in the matter of wear of parts and reduction of tractive effort on grades, curves and in starting. Finally, such disagreeable concomitants as odor, noise, or danger of explosion must be excluded if the independent motor is to be an entire success.

Modern street railroading requires constantly increasing average speeds over city streets without increasing danger of accident. With the short runs between streets, and the many stops necessary for taking on and letting off passengers, high average speeds can be obtained only by means of high rates of acceleration in starting, and correspondingly high-braking effort in stopping. In other words, maximum speed must be reached as quickly as possible and kept up as long as possible before brakes are applied.

Now, the one propelling agency adapted for this peculiar class of work, so far developed in the entire transportation field, is the electric motor, with its constant rotary effort, or torque, and with its almost infinite capacity for automatically absorbing and transforming electric power into a rotary effort. A little 25 horse-power car motor can be overloaded 100 per cent. or more if the occasion requires, and will take current until its wires actually melt in the process. There is no such reserve power in any form of reciprocating motion engine—no such constant torque, and no such ease of control. Compressed air, stored steam, gas, petroleum and other motors all have their possibilities of development, mechanically and commercially, and when proven successful in practice on any considerable scale, there will be certain portions of the general transportation field open to them, but it is equally true that the electric motor has intrinsic advantages such that it will never be displaced in street railway service, while it is certain also that it will reach into larger transportation work now performed exclusively by steam locomotives.

Before proceeding further with electric motors, a word should be said about the cable system. It would appear at first sight that here also is found a system which would fulfil the requirement of maximum acceleration and braking possibilities, and consequent high schedule speeds. Maximum acceleration can certainly be obtained with the cable, as has frequently been demonstrated by a surly or incompetent gripman, to the great discomfort of passengers, but no cable line can compete with a parallel electric line in point of schedule speed, for the reason that the maximum speed is limited to the speed of the cable, and the latter must be kept down to a point such that slippage through the grip is not continuous. In other words, there is little possibility that cable cars, once behind their schedules, can catch up to them unless by rare good fortune in not being required to stop for passengers, while with the electric cars there is always the possibility of flying through the streets in the suburban or less congested streets, so as to make up time lost elsewhere. As a matter of fact, the cable is disappearing from American street railroads, partly because it is not popular, as it is found that the people always prefer parallel electric lines because of the greater smoothness in running, and partly because of the greater economy in operation, demonstrated again and again in our leading cities, where both motive powers have been used. The cable system is a complicated one, with its immensely costly and cumbersome street construction, which requires constant care and attention, and it is true, moreover, that a cable line cannot be sectionalized to the extent that an electric line can be done, to the end of minimizing the stoppage of traffic.

Granting, therefore, that the electric motor is the city transportation agency of the present and the future, there remains to be considered the relative advantages of the overhead system, the conduit system and the storage-battery system. In spite of numerous attempts to put the latter system upon a commercial basis, it has not yet been demonstrated to the satisfaction of street railway managers that it can be used with economy on a large scale or that good acceleration and grade-climbing work can be done where storage batteries alone are depended upon for reserve and contingency requirements. The equipment of the Chicago and Englewood Street Railway with storage batteries is about the only ambitious experiment on a scale that is now being tried in this country, but abroad batteries are used quite largely and successfully in what is called the "mixed system," in which the overhead-trolley system is used for suburban and outlying lines, and storage batteries for the business centers. The great difficulties in the way of storage-battery work for transportation purposes lie in the great weight of the batteries to be transported, the deterioration of the plates, particularly when called upon for the widely varying power requirements of a street car, and the somewhat sluggish action of the cars in acceleration. It is by no means unreasonable to hope, however, that improvements will come in this line such that commercially successful storage-battery cars may be made possible.

The central-station method of operating street railway systems, particularly by electricity, has many intrinsic advantages. In the first place, power can be generated at such stations in large quantity and at extremely small expense. It is probable that in the largest street railway power station in the world, now building in New York, the cost of power will be reduced to $\frac{3}{4}$ of a cent per car mile, or less than 8 per cent. of the total operating expenses of the system, this cost including all losses of generation, conversion, transmission and reconversion. The inherent advantages and possibilities of electric transmission for power purposes are such that it is difficult to conceive of a more perfect adaptation of means to the desired end. When, however, the matter of transmission is taken up in detail, three methods present themselves for selection, the overhead-wire system, the open-slot conduit system, and the surface-contact, or "button system."

The overhead-wire system is the one in almost universal use, and the wisdom of its adoption has been completely justified in a large majority of cases. It is inexpensive to install, as compared with the other two systems; it is, when well put up, probably more economical than either, and troubles can be easily located and quickly remedied. Its chief disadvantages from the public point of view is the so-called unsightliness of poles and wires. In the early days of electric traction, there was certainly grave cause for complaint about this feature, but since then the improvements have been so radical that it has no longer great force, while the danger of falling wires and of obstruction to firemen in the discharge of their duty has also been done away with to a very large extent, so that there are to-day as few accidents of any kind from the operation of trolley cars in our principal cities as could possibly be expected, in view of the immense number of passengers carried, and the congested conditions of the streets.

The surface-contact, or " button system," is not in use on any large scale in this country, but a large installation has just been made in Monaco, which is said to be working successfully. The chief trouble with this system lies in the employment of a great number of pieces of mechanism, more or less complicated, and liable to failure, the number usually being 500 at least per mile of single track. Theoretically, the system is an excellent one and has many points of advantage, but it has not come into common use as yet, and time only will tell whether or not the mechanism can be kept in good working order indefinitely without constant danger of " tie-ups " or delays.

The open-slot conduit system is in use in America only in New York City and Washington. In New York it has cost probably ten times as much as an overhead system would have cost to accomplish the same results, and its operating expenses are probably about the same as, or perhaps slightly less than those of the equivalent overhead-trolley system.

The city of Glasgow, Scotland, in common with many other British and European cities, has before it to-day the problem of determining which of these three varieties of electric traction shall be adopted. Glasgow has had some experience with the overhead system, and knows that it is reliable, reasonable in first cost, and economical in operation. The favorable results obtained on the conduit lines of New York, Washington and a few European cities have been studied in Great Britain and elsewhere with the greatest care and interest, and yet it has been determined in Glasgow and other places to use the overhead system in preference to the conduit. The fact is that it is only in cities where great traffic density obtains, and where the mileage to be equipped is comparatively small, that it is possible to pay interest upon the enormous investment requisite for the conduit system, and this is particularly true if this investment has to be piled up upon that for previous improvements, such as the equipment of horse lines with the overhead system. Moreover, the climatic conditions must be favorable in order that success with any form of conduit system may be assured, and the sewerage system must be perfect; for, unless the conduit can be kept perfectly clean and free from snow and accumulations of water, serious electrical troubles will occur, which may tie up a railway in whole or in part. If the street railways in this country now operating on the overhead electric system were compelled to change to the conduit system over their entire lines or any large portion of them, financial ruin would undoubtedly be the consequence.

All these problems of motive power have had to be faced by managers in this country, and are now before the tramway managers of Europe. They are wise in their generation who have looked and are looking forward to the future of their properties and of the cities in which they are located, and who recognize the importance of the part which local transportation plays in the onward march of a great and constantly growing city. The real interests of the people and of the private capital engaged in street railroading are, or should be, substantially the same. The ideal system for both is one which can be handled with the greatest certainty in operation, and which can be indefinitely extended into suburban territory in advance of population without too great cost and without the necessity of transfers, and which can be built at minimum expense for the advantages given. It cannot be for the public interest to load down street railway companies with constantly increasing burdens, such as the adoption of the most costly forms of motive power, if cheaper would answer the purpose; for, by doing so, they thus postpone still further the time when any reductions can be made in fares or a system of profit-sharing with the city can be established.

[*To be Concluded.*]

NOTES AND COMMENTS.

ELECTRICAL EQUIPMENT OF A STEAM RAILWAY.

An interesting case of the successful conversion of a steam railroad into an electrically operated one is that of the Buffalo and Lockport Branch of the Erie Railroad, which runs from Tonawanda to Lockport, N. Y. The new equipment consists of two 36-ton electric locomotives for freight service, and ten electric motor cars for passenger service. The new system was put in operation last summer, and is said to be giving the greatest satisfaction. The electric cars are run at intervals of one-half hour, instead of the large intervals between trains, as was the custom with the steam road, so that five cars at this rate are required to operate the twenty-five miles of railway between Buffalo and Lockport. On their first trip the electric cars attained a speed of fifty miles an hour, including stops.

The transformation of this line from a steam to an electrically operated road, the *Iron Age* says, marks an important step in the employment of current on the steam road. If in its operation it successfully attains the results expected, it will conclusively prove that electricity can be economically applied to the operation of branches and feeders of steam trunk line systems. It would be too much to expect an immediate conversion of these latter main lines from steam operation to operation by electricity, but with electric locomotives and motor cars profitably carrying on both freight and passenger traffic on their feeders, the entering wedge will be driven still further and the ultimate result will be so much nearer of attainment. W.

FUTURE OF THE GAS ENGINE.

The *British Journal of Gas Lighting* publishes an interesting paper lately read by Mr. W. C. Peebles before the North British Association of Gas Managers. In this, the author gives a historical sketch of the development of this type of motor and discusses the lines along which the gas engine is likely to be further developed as a commercial machine in the future.

Mr. Peebles' views are summarized in the following conclusions: "There can be no doubt that a great deal has yet to be done to improve the action of the gas engine. The main direction in which a change is to be looked for is, I think, in the cycle. But this would seem to be almost impossible without introducing complicated mechanism. At present—at least with the smaller sizes—the successful competition of the gas engine with the steam engine is due chiefly to the convenience and economy with which the gas engine can be operated, especially for intermittent work. With engines above 40 or 50 horse-power, using producer gas, the cost of working as compared with steam is very greatly in favor of the gas engine, as has been proved time after time. We shall find, therefore, that the large gas engines will not stop at 400 or 500 horse-power; but will increase gradually until they compete in power with the largest steam engines made." W.

THE "SKY-SCRAPER" NOT A MODERN INSTITUTION.

Professor Lanciani, according to *Architecture and Building*, has been making some curious discoveries in reference to the building laws in force in ancient Rome, from which it would appear that the extravagantly high buildings which we are accustomed to consider as exclusively American in origin, were quite well known in Rome, and were the subject of restrictive legislation, for much the same reasons that they are objected to to-day, viz.: dangers from fire, danger from deterioration of the strength of the structures themselves, complaints of the darkened streets, etc.

The following, from the journal above named, will serve to explain the situation as disclosed by Professor Lanciani's researches :

"There are frequent allusions among the Roman historians * * * to the enormous height of the tenement buildings of Rome, but no definite figures are given until the days of Augustus, when a law was promulgated by the Senate which fixed the height of new structures at 60 feet on the street front without making any allusion to the height of the rear. It is, however, known that, in the rear, these tenement buildings rose often several stories higher than in the front, so that from a distant height, as from the top of a temple which commanded an extensive view, a row of tenement buildings in Rome presented the appearance of a terrace--highest in the rear and descending by stories toward the front. The law of Augustus applied to new buildings, respect, then as now, being shown for investments already made. The number of stories on the street front of these Roman buildings was generally ten or twelve, with fourteen or fifteen in the rear. The lowest stories were 8 or 10 feet in height, but from accounts given by writers of that time, the stories would appear to have gradually diminished as their height above the ground increased, so that the topmost tenants lived in quarters where very often they could not stand erect.

"That the stories were sometimes much less than 5 feet is shown by the discoveries in Pompeii, where, in a house inhabited, presumably by poor tenants, a story of 4 feet 3 inches has been discovered. This was a living room, too, for in it were found all the articles which pertained to Roman housekeeping—cooking utensils, beds, stools, mirrors, combs, brushes and other things, which, with the bones of the family, furnished indisputable evidence that the room had been occupied. * * * That the tenement houses of Rome towered at least 100 feet above the street in front, and 125 to 130 feet in the rear, is certain, for the promulgation of an edict limiting the height to 60 feet in front, indicates that this height had been so greatly exceeded in so many cases, that the public safety was believed to be imperilled. How many stories were contained in these tenements is conjectural, but if the upper stories were no higher than that of the house in Pompeii, the Roman tenements may have contained as many or more stories than the modern office building."

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, March 15, 1899.*]

HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, March 15, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 172 members and visitors.

Additions to membership since last report, 45.

The Actuary reported the gift of the sum of One Thousand Dollars from Mr. John T. Morris, for the foundation of a fund to be known as the "James T. Morris Memorial Fund," the income of which is to be devoted to the purchase of books on mechanical subjects for the library of the Institute. It was also reported that the sum above named had been received and placed in the hands of the Board of Trustees for investment.

It was voted that the action of the Board of Managers in accepting this gift be endorsed, and that the thanks of the Institute be tendered to the donor.

Mr. E. G. Acheson, of Niagara Falls, N Y., presented a paper on "Graphite and its Artificial Manufacture," which was illustrated by the exhibition of a number of specimens, showing the partial and complete conversion of carbon into the graphitic state by the electric-furnace process devised by the speaker.

The subject was referred to the Committee on Science and the Arts for investigation and report.

Mr. Philip Mauro, of Washington, presented a communication on the "Development of the Talking Machine," particularly referring to the graphophone and its most recently improved form—the Graphophone-Grand. The paper was illustrated by the exhibition of the old and new forms of the apparatus, with which a number of demonstrations were made.

The subject was also referred for investigation.

The President called attention to the fact that a bill was now pending in the Legislature of the Commonwealth providing for an annual expenditure of $20,000, to be met by an equal sum supplied by the Federal Government, to be devoted to the making of a topographical and geological survey of the State. The President made some comments upon the importance of this contemplated work to the citizens of the Commonwealth, whereupon it was voted "that if upon investigation it should appear that the bill above referred to fully meets the requirements, the President and Secretary of the Institute be authorized to transmit the approval of the Institute of the bill now pending in the Legislature making an appropriation for the conduct of a topographical and geological survey of the State of Pennsylvania."

The President announced the following Standing Committees of the Institute for the current year:

Committee on Library.

Prof. F. L. Garrison,
Mr. Louis E. Levy,
Prof. Geo. F. Stradling,
Dr. Isaac Norris,
Mr. Edwin S. Balch,
Dr. Harry F. Keller,
Mr. Arthur Falkenau,
Mr. Benj. S. Lyman,
Mr. A. M. Greene, Jr.,
Mr. Wm. M. Barr.

Committee on Meetings.

Mr. Washington Jones,
Mr. Spencer Fullerton,
Mr. Henry R. Heyl,
Prof. Jos. W. Richards,
Prof. Geo. A. Hoadley,
Mr. James Christie,
Mr. J. Y. McConnell,
Mr. Geo. H. Taber, Jr.,
Mr. W. N. Jennings,
Dr. A. E. Kennelly.

Committee on Meteorology.

Prof. Geo. A. Hoadley,
Prof. Edgar Marburg,
Mr. L. Y. Schermerhorn,
Mr. Henry Birkinbine,
Mr. Thomas Shaw,
Mr. Jos. T. Richards,
Mr. Henry Gawthrop,
Mr. Geo. S. Webster,
Mr. John E. Codman,
Prof. L. F. Rondinella.

Committee on Cabinet of Models.

Mr. Henry Howson,
Prof. A. J. Rowland,
Mr. Philip Pistor,
Mr. L. L. Cheney,
Mr. W. L. Boswell,
Mr. Francis Schumann,
Mr. Frank M. Sawyer,
Mr. Chas. H. Gifford,
Mr. John G. Baker,
Mr. Strickland L. Kneass.

Committee on Cabinet of Minerals and Geological Specimens.

Mr. Benj. S. Lyman,
Dr. Wm. C. Day,
Mr. E. V. d'Invilliers,
Mr. Theo. D. Rand,
Mr. Clarence S. Bement,
Dr. Lee K. Frankel,
Prof. Lyman B. Hall,
Dr. Wm. H. Greene,
Mr. Andrew A. Blair,
Dr. F. A. Genth, Jr.

Committee on Cabinet of Arts and Manufactures.

Mr. Edw. T. Child,
Mr. Cyrus Chambers, Jr.,
Mr. S. M. Vauclain,
Mr. John F. Simons,
Mr. Henry J. Hartley,
Mr. John Haug,
Mr. Benj. H. Gledhill,
Mr. James M. Dodge,
Mr. H. F. Colvin,
Mr. A. E. Outerbridge, Jr.

Adjourned.

WM. H. WAHL,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held March 1, 1899.*]

PROF. EDGAR MARBURG in the chair.

Reports on the following subjects were considered :

Machine and Cutter for Generating Gear-Teeth.—E. R. Fellows, Springfield, Vt.

Laid over one month.

The following were adopted :

Gas Composimeter.—Uehling and Steinbart Harrison, N. J.

ABSTRACT.—This device is designed specially for the purpose of analyzing and recording the percentage of carbonic acid in furnace and flue gases, and is continuous in operation. It is identical in principle with the Uehling and Steinbart pyrometer, lately investigated by this Committee. Both instruments employ, as a measure, the reduction in volume of the gases, which takes place in a chamber, of which two apertures form respectively the inlet and outlet, and through which the gas is constantly drawn by suction. If, from the stream of gas flowing through this chamber, one of the constituents is continuously removed by absorption (say carbonic acid by caustic alkali), a reduction of volume takes place.

Every change in the volume of the constituents absorbed from the gas causes a corresponding change of suction in the chamber, and this change is assumed to be a true measure of the percentage of the constituent in the gas to be measured.

The apparatus may be applied to a single boiler or furnace or to a number. In the latter case, a single aspirator is employed of sufficient size to produce the required suction for all, controlled by a single large suction regulator.

A simple recording apparatus is employed, by which a graphical chart showing the condition of the combustion in the furnace (or furnaces respectively) is continuously exhibited to the operative in charge. This combination adds greatly to the practical value of the device. The details of the device can only be made intelligible with the aid of illustrations.

The investigating committee made a number of tests of an apparatus of this description installed in the Spreckels' Sugar Refinery in Philadelphia, on which its report is based.

The report is favorable. The results obtained in a number of observations with the apparatus, when compared with the results of chemical examination of the flue gases withdrawn for comparison, exhibited a satisfactory uniformity.

The committee recommends the grant of the John Scott Legacy Premium and Medal to the inventors. [*Sub-Committee.*—John M. Hartman, Chairman ; James Christie, Harry F. Keller.]

Universal Trimming Shear.—Reinhold Bettermann, Johnstown, Pa.

ABSTRACT.—This invention consists in concaving the cutting side of the blade of a shear, between the cutting and upper edges, so that, in cutting curved shapes, as the sheet is fed longitudinally with the line of cutting, it can also be forced sideways into the recess in the upper blade, thus continually altering the line of cut, and producing curves of shorter radii than can be cut with shears having the upper blade a plane surface.

The report finds that concaving the blade weakens the cutting edge and would cause it to crumble in heavy work; also, grinding the cutting edge of a concave blade would cause cleavance between the cutting edges of the upper and lower blades, requiring a liner to be inserted between the blade and the jaw. The Sub-Committee's opinion is therefore unfavorable. [*Sub-Committee.*—Spencer Fullerton, Robert D. Kinney, Henry F. Colvin.]

Power-Driven Shear with Adjustable Stroke. (Same inventor.)

ABSTRACT.—This device was invented by Mr. Bettermann as an auxiliary, but not indispensable to the successful action of his concaved upper knife for shears. It consists in dispensing with a fly-wheel in an ordinary geared power-shear, and driving the countershaft by a straight belt, and reversing it by a cross-belt, running on loose pulleys, with friction-clutches on the countershaft. The clutches are connected by levers and links with the ram, so that the motion of the ram at any desired point of the down-stroke, will reverse the countershaft and withdraw the blade before finishing its maximum cut.

In the opinion of the investigating committee, this reverse motion is utterly impracticable for shears, except, perhaps, for cutting very thin iron. There being no fly-wheel, and the shafts being reversed at every stroke, there is no momentum of continuously revolving parts, and the power of the shear is reduced simply to that derived from the belt during the time of the actual cut. [*Sub-Committee.*—Spencer Fullerton, Robt. D. Kinney, Henry F. Colvin.]

Combination Pneumatic Elevator and Grinding Mill.—C. A. Gerdtzden, Winona, Minn.

ABSTRACT.—This device consists of a vertical iron mill with a grinding plate bolted on the end of a rapidly revolving shaft. This idea is not new, although the method of fastening the bed-plate is novel. The committee, however, considers this feature impracticable in a fast-running mill.

The pneumatic-elevator feature of the invention is also old, and the committee is of the opinion that the applicant will find, as others have found, that the mill itself will not make sufficient draft to elevate material any distance, no matter how many rings are added to the mill plates. Applicant is advised that there is nothing of merit in his proposed device. [*Sub-Committee.*—A. Robinson McIlvaine, Chairman, Luther L. Cheney.]

Primary Electric Clock.—Carl Joseph Moberg, Jersey City, N. J.

This instrument is an electrically actuated clock. The report criticises adversely the escapement, the defects of the impulse, the contact (time train), the contact (striking), the striking and the gear-train supporting frames.

The construction of the pendulum bob is found to be novel. The report concludes that, while the construction presents some features which differ from that of other clocks of the same order, there are no new features which can be considered as improvements on devices which have been in use heretofore. [*Sub-Committee.*—Wm. T. Lewis, H. R. Heyl, Fred. T. Haschka, L. Breitinger.]

SECTIONS.

(*Abstract of Proceedings.*)

CHEMICAL SECTION.—*Special Meeting*, Tuesday, January 3, 1899, Dr. Wahl in the chair.

Dr. W. J. Williams, Chemist to the United States Arsenal, Frankford, Philadelphia, read a paper on "Methods for the Examination of Explosives," illustrated with specimens of various forms of explosives and apparatus for testing the same. [The paper is printed in full in the *Journal*, Vol. CXLVII, 197, *et seq.*]

Stated Meeting, Tuesday, January 17th. Dr. Richards in the chair.

The following officers were elected: President, Dr. Joseph W. Richards; Vice-Presidents, Dr. Bruno Terne, Dr. W. J. Williams; Secretary, Mr. Waldemar Lee; Conservator, Dr. Wm. H. Wahl.

Mr. Allen Hazen, of New York, read a paper on "The Clarification of River Waters." [The paper is published in the *Journal*, Vol. CXLVII, 177.]

Stated Meeting, Tuesday, February 21st, Dr. Richards in the chair.

The following communications were presented:

"A Process for Testing Metals." By Mr. Joseph Richards.

"The Laboratory Production of Asphalts from Animal and Vegetable Materials." By Dr. W. C. Day, Swarthmore College, Pa. Discussed by Dr. S. F. Peckham, Dr. Samuel P. Sadtler, Dr. Harry F. Keller. Both papers were referred for publication.

A communication was presented proposing the formation of a Photographic and Microscopic Branch of the Section. Dr. Wm. H. Greene and Dr. Wm. H. Wahl were named as a special committee to confer with the petitioners, with power to make all needful arrangements to organize the new subsection.

Special Meeting, Tuesday, March 7th, Dr. Richards in the chair.

The following communications were presented: "An investigation of the Recent Explosion in the Capitol at Washington." By Prof. Chas. E. Munroe, Columbian University, Washington, D. C. "A New Liquid Acetylene Diodide." By Dr. Edward H. Keiser, Bryn Mawr College, Pa.

Stated Meeting, Tuesday, March 21st, Dr. Richards in the chair.

Dr. H. Carrington Bolton, Washington, D. C., presented a communication entitled: "The Development of Pneumatic Chemistry," illustrated profusely with lantern slides.

ELECTRICAL SECTION.—*Stated Meeting*, Tuesday, January 24, 1899. The following officers were elected: President, Prof. Geo. F. Hoadley; Vice-Presidents, G. U. G. Holman, S. B. Locke; Secretary, George T. Eyanson; Conservator, Dr. Wahl.

Professor Hoadley, President, in the chair.

Mr. W. H. Tapley, United States Government Printing Office, Washington, D. C., read a paper on "The Practical Application of the Electric Motor to

Printing Press Machinery," which was referred to the Committee on Publication.

Stated Meeting, Tuesday, February 28th, Professor Hoadley in the chair.

The following communications were presented:

"Some Laboratory Methods in Electricity" (with illustrations). Prof. W. S. Franklin, Lehigh University.

"Notes on Some Recent Developments in Electrical Engineering." Mr. Carl Hering.

"Experimental Demonstration of a New Electrolytic Interrupter for Induction Coils." Mr. Elmer G. Willyoung.

"Experimental Demonstration of an Improved Static X-Ray Machine," made by the American Roentgen Ray Company, Boston. Mr. Balderston (Williams, Brown & Earle, Philadelphia).

Stated Meeting, March 28, Professor Hoadley in the chair.

This meeting was devoted to the presentation, in abstract, of papers on electric railway subjects, by Messrs. Frank J. Sprague, Albert B. Herrick and Edward E. Higgins. The discussion was opened by Mr. Chas. Hewett, of the Union Traction Company, Philadelphia.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, Wednesday, January 11, 1899, Mr. James Christie in the chair.

The annual election of officers resulted as follows: President, James Christie; Vice-Presidents, Dr. D. K. Tuttle and Mr. Joseph Richards; Secretary, G. H. Clamer; Conservator, Dr. Wahl.

The annual report of the Section was presented by the Secretary and approved. Ordered to be transmitted to the Institute.

The following communications were presented:

"Segregation Tests on Steel Ingots." Mr. A. W. Allen, Pencoyd Iron Works.

"The Mogollon (N. M.) Mining District." Dr. H. M. Chance, Mining Engineer.

Freely discussed and referred for publication.

Messrs. B. S. Lyman, A. E. Outerbridge, Jr., and A. W. Allen were appointed as members of the Standing Committee on Papers.

Special Meeting, Wednesday, January 25th, Mr. James Christie in the chair.

The proposition was considered that the Section should interest itself in the work of the International Association for the Testing of Technical Materials.

It was thereupon decided to recommend that the Institute as a body should join the Association.

A resolution was passed favoring an appropriation by Congress in support of a Mining and Metallurgical Bureau in connection with the work of the U. S. Geological Survey, and urging the Senators of the State of Pennsylvania to support the measure.

Mr. Geo. C. Davis, of Philadelphia, presented a paper "On the Early History of Malleable Cast-Iron in the United States."

In the absence of the author, Mr. H. P. C. Nitze, of Baltimore, Dr. Jos. W.

Richards presented for him a paper "On the Iron Ores of the Ural Mountains."

Stated Meeting, Wednesday, February 8th, Mr. Christie in the chair.

The following papers were read:

"Notes on the Reduction of Iron Ores." John M. Hartman.

"Subterranean Ice Deposits in America" (illustrated). Edwin S. Balch. (Referred for publication.)

Special Meeting, Thursday, February 23d, Mr. Christie in the chair.

Prof. J. F. Kemp, of Columbia University, New York, read a paper on "Titaniferous Iron Ores."

Freely discussed and referred for publication.

Stated Meeting, Wednesday, March 9th.

Prof. Wm. H. Burr, of Columbia University, New York, read a paper on "Some Features in the Architectural Design of Buildings," which was profusely illustrated with the aid of lantern slides. The paper evoked an extended discussion. (Referred for publication.)

Special Meeting, Wednesday, March 22d, Mr. Christie in the chair.

Prof. Angelo Heilprin, Philadelphia, gave a lecture, entitled "Observations on the Physical History of the Klondike Gold Region, with Incidents of a Recent Journey Thither." The speaker illustrated his lecture with the aid of a number of lantern views.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, Thursday, January 12, 1899.

The following officers were elected: President, Wilfred Lewis; Vice-Presidents, Strickland Kneass and F. M. Jaquith; Secretary, D. Eppelsheimer, Jr.; Conservator, Dr. Wahl.

Mr. Lewis in the chair.

The subject for discussion was "Personal Reminiscences of Changes in Machine Design and Shop Practice."

The discussion was opened by Dr. Sellers, and was participated in by Messrs. W. Jones, Fullerton, Spangler, Heyl, Wiegand, Outerbridge, Fitts, Chambers and many others.

Stated Meeting, Thursday, February 9th, President Lewis in the chair.

The subject for discussion was "Traveling Cranes," and was opened by Mr. Outerbridge, and largely participated in by members and others.

Special Meeting, Thursday, February 16th, Mr. Kneass in the chair.

Prof. Wm. S. Aldrich, of West Virginia University, gave an illustrated lecture, entitled "Engineering and Naval Experiences in the U. S. Repair Steamer 'Vulcan.'"

Stated Meeting, Thursday, March 9th, Vice-President Kneass in the chair.

The subject for discussion was "The Commercial Applications of Compressed Air," opened by Mr. W. L. Saunders, of New York. A large number of members participated. Mr. Saunders' communication was referred for publication.

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JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVII, NO. 5. 74TH YEAR. MAY, 1899

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE FRANKLIN INSTITUTE.

Stated Meeting, February 15, 1899.

ACID BLAST PROCESS FOR ETCHING.*

BY LOUIS EDWARD LEVY,
Member of the Institute.

The present device, which may be termed an Acid Blast, while primarily intended to facilitate the etching of photochemical printing plates is also applicable in all cases where the chemical erosion of metals or of glass is to be effected. The invention consists essentially in the application of a powerful blast of atomized acid or other erodent in place of the customary immersion bath. Along with the means of producing the requisite blast of comminuted acid and of applying it for the purpose in view, there is combined an arrangement for the necessary washing of the plate, which affords an increased convenience of procedure and a consequent saving of time in the course of the work.

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* Abstract of a paper on a new method of etching, read in connection with a demonstration of the invention, at the stated meeting of the Institute, February 15, 1899.

Preliminary to a description of the blast method of etching a cursory review of the customary immersion process may be desirable. The preparation of the design for the etching process being the same for the blast as for the immersion method, the details of that procedure need not be dwelt upon. The erodent must, of course, be adapted to the work required, and be in fluid form; thus, for the etching of a zinc plate a solution of nitric acid may be regarded as preferable; for copper, a solution of iron chloride; for glass, its well-known solvent, hydrofluoric acid, etc.

Assuming the plate to be of zinc and the design as having been produced on it in some fatty ink by the usual photographic process, the plate is prepared for the etching process by first melting into combination with the inked image some resinous powder to strengthen it against the action of the acid, and then protecting the back of the plate by smearing it, while still warm from the first melting, with a covering of shellac or asphaltum varnish.

The plate having cooled, is now immersed, face upward, in a flat bath of dilute nitric acid. The acid enters into combination with the exposed metal, and the surface of the plate is immediately covered with a layer of minute bubbles of hydrogen gas, which, if the action proceeds undisturbed, gradually combine into larger bubbles that finally rise to the surface. Coincident with the development of the gas bubbles there is formed a deposit of zinc nitrate, which adheres to the plate as a dark scum, except where it is lifted from the surface by the larger bubbles as they arise. The bubbles and the deposit would, if left on the plate, retard the action of the acid and cause it to proceed unevenly, and to avoid this the etcher, with a suitable brush, removes these obstructions from the plate.

It is plain that the acid tends to combine with all of the metallic surface that is exposed. Accordingly, as soon as the plate is immersed in the bath, the etching proceeds not only downwards, but sidewards into the plate as well. The resistant which forms the design protects the surface of the underlying metal from the corrosion of the acid, but if the lines or stipples of the design be thin, say an hundredth of an inch wide, the acid, eating its way on both sides of the lines, will cut sidewards through the one-hundredth of an inch thickness by the time it has etched downwards one-half as much. Consequently where thin lines or stipples have to be retained in the plate, as in the case of fine line or stipple drawings, the etching must be halted at a very shallow depth, and the sides of the lines protected from the action of the acid.

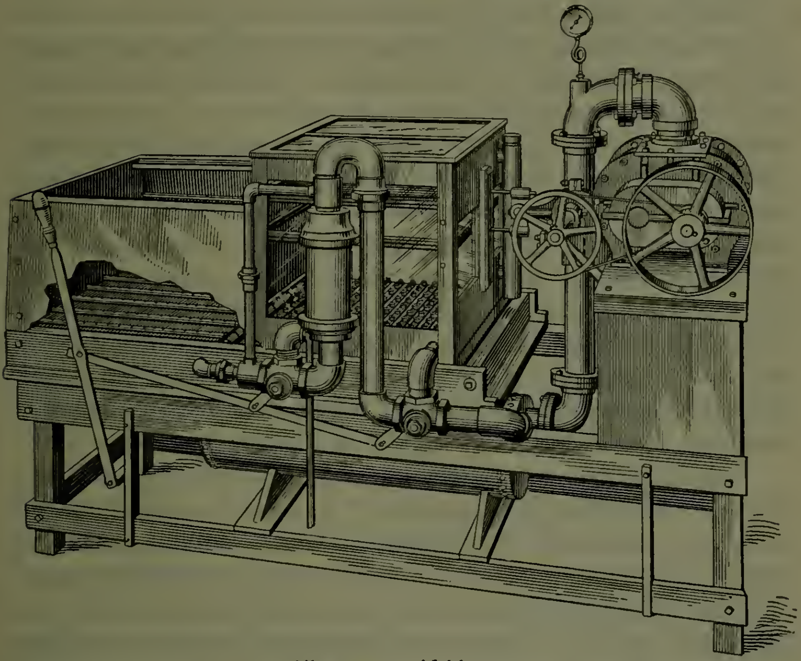
This is done by covering the exposed sides of the lines with some resinous powder carried over the plate at an angle to its surface by means of a camel's-hair brush. This operation requires a trained and skillful hand; when the powder is properly distributed, the plate is heated, the powder melted in place, and the plate then cooled. This procedure is repeated, the powder being brushed successively in four opposite directions across the plate, and when completed, the latter is ready for the so-called "second etch."

The depth to which this second etching can be safely carried depends largely on the extent to which the resinous powder has been deposited by the etcher against the base of the lines, which is varied by the operator according to the character of the work itself. The etching is permitted to proceed downwards until the lines or stipples begin to be jeopardized by the sideward action of the acid. This condition results the sooner by reason of the fact that the acid covering the plate is forced over it horizontally to and fro by a rocking motion given to the trough containing the bath, a proceeding which is requisite not only to expedite the work, but also to diffuse the heat generated by the erosion. Meanwhile, the brush has to be applied assiduously over the plate, to remove the bubbles and the deposit as they develop. When the sides of the lines have become bared to the point of danger, the work is again halted and the four-way powdering operation is repeated to prepare the plate for the "third etch." This usually suffices to enable the etching to proceed to a point beyond which any further deepening required is left to the router, but for specially fine work the etching is not allowed to proceed so far, and the covering of the lines is repeated for a fourth or fifth time.

After the third powdering, which usually covers all the closer depressions of the etching completely, a stronger solution of the etching liquid can be used, the etcher regulating the work with his brush, the tray being meanwhile rocked, either mechanically or by the etcher himself, to further the even action of the acid.

The process of etching a zinc line plate usually takes from one and one-half to two and one-half hours, according to the depth of the etching required, which varies with the character of the work itself. Newspaper illustrations are frequently etched to a practicable depth in an hour's time, but often at the expense of the quality of the result. The strong acid solution required in such a procedure is apt to cut through the thin protection of the edges of the lines, and leave them serrated, or, as it is technically called, "rotten." Coincidently the rapid combination of the acid with the metal heats the plate and the liquid, which necessitates the addition of ice to keep down the temperature and prevent the etching ground from giving way through softening, and which furthermore gives rise to fumes that are very deleterious to the etcher, few operators being able to continue at such work permanently.

With the etching blast the time required to complete an etching is materially shortened and the etcher is freed from the necessity of breathing in the gaseous products of the etching process. At the same time, the technical qualities of the result are secured in a degree obtained only by the best hand-etching, both as regards the delicacy of the lines left in relief and the depth of the etching between the closest lines or stipples of the design. The plate, prepared as has already been noted, in the usual manner, is clamped against a carrier board, face upward, and the back of the plate, being fixed closely against the surface of this board, is thus protected from the action of the blast of acid, and therefore needs no covering of protecting varnish, nor the removal of such covering after the etching is finished, as is the case with the immersion method. The board carrying the plate is now placed, with the design face downward, in an open frame which is slid into another movable frame within the etching box. This inner frame, carrying the sliding frame with the board and plate, is connected by a rod to an excentric worked from the driving shaft of the compressor. The motion of this shaft, thus imparted to the inner frame, gives the latter, with its contained carrier and plate, a reciprocal movement through a space equal to the distance between the nozzles of the aspirators below.



The Levy acid blast.

The etching box, preferably made with glass sides, is open at the bottom and is placed in a tray or tank containing a solution of the acid. Under the surface of the liquid are a series of tubes connected with an air compressor and provided with a large number of atomizing nozzles which protrude above the surface of the liquid. When the air compressor is set in motion and the air current directed into the tubes and out of the protruding nozzles, the acid is sucked in through openings in the bottoms of the aspirators and projected upwards in the form of an atomized spray against the surface of the plate. The aspirators are so arranged that the spray, at the point of its contact with the plate, is a homogeneous body of acid vapor moving towards the plate at a right angle to its surface and with a velocity which causes it to impinge on the plate with a forcible impact. The result is a very rapid etching of the plate by the acid, and the procedure of this etching to a very considerable depth without any undercutting.

The rationale of this process becomes apparent on a cursory consideration of the matter. The minute particles of acid impinging against the plate have their normal force of chemical affinity enhanced by the force of their impact, which results in each particle of the acid becoming saturated with the metallic base immediately on contact with the latter, and thus losing the power of further dissolving the metal in any direction. Each succeeding particle impinges in the direction in which the etching is desired to proceed, and the process can be safely continued to a depth beyond which the finer and closer lines of the design would become too frail to stand the strain of printing, at which point the etching is stopped and the finer lines protected by filling in with powder in the usual way.

The rapid decomposition of the metal by the acid develops an amount of heat which, if not counteracted, would soon warm the plate to a degree where the resinous resistant would soften and give way. The necessary counteraction is effected by the expansion of the compressed air as it escapes from the aspirators, which results in the absorption of even more heat than is developed on the plate. This keeps the plate and the etching liquid quite cool, even in warm weather, and consequently avoids the necessity of applying ice for the purpose.

The bubbles of hydrogen and the metallic scum which form on the plate in the course of the chemical process, are cleared off by the force of the blast as fast as they develop, and thus the necessity of the operator standing over the work to remove these obstructions is avoided.

The gases and vapor fumes, which are so abundantly generated in a rapid chemical decomposition, are carried off by the escaping air current through a ventilating chimney from the interior of the etching-box. The work-room is thus kept free from these deleterious vapors, and the health of the operator is secured against their effects.

The etching liquid carried by the blast may, of course, be varied for different requirements. In etching copper by means of iron chloride the gain of efficiency, as compared with the immersion method, is as marked as in etching zinc with nitric acid. Half-tone or crayon stipple effects on zinc are rendered by this method at least as perfectly as by the current methods on copper, and with a great saving of time, apart from the saving in cost of the material. The thorough rendering of half-tone reproductions in zinc etchings by the immersion method, though quite feasible, requires intelligent and skillful handling, the work being much less automatic than in the etching of copper half-tone effects with iron chloride. With a blast of atomized dilute nitric acid a half-tone etching on zinc can be produced in two minutes, with a purity of the edges of the lines and stipples fully equal to that obtainable on copper with the immersion bath, and with a far greater depth of the etching.

The washing appliance connected with the blast is operated as follows:

While the air blast is passing to the aspirators through pipes connected by a three-way cock, another such cock is open to permit a water supply to enter a reservoir. When the plate is to be washed, the frame with the plate carrier is pulled out from the etching box and slid over to an adjacent compartment, at the bottom of which are fixed a series of perforated pipes. A thrust of a lever connecting the two three-way cocks turns the air current from the direction of the aspirators through another pipe to the top of the water reservoir, at the same time turning off the supply from the latter and opening a way for the water from the reservoir to the perforated pipes beneath the plate. The air pressure forces out the water in a sharp jet against the plate and washes its entire surface clean in a few seconds.

The etching and the washing compartments occupy each a half of a single tank, divided in the middle by a partition. Passing through this partition at the bottom, under the level of the latter, is a movable L-shaped tube, which, when the outer arm is in vertical position, determines the level of the liquid in the etching compartment. A small quantity of the liquid being carried off with each plate and washed away by the water-jet, this loss is made good by a replenishment of fresh and slightly stronger acid solution, which suffices in practice to keep the etching liquid up to its normal strength and quantity.

A considerable saving of the acid or other etching liquids is thus effected, there being here no occasion for the constant renewal and wastage of the acid, which is inevitable in the current practice.

When the etching liquid is to be removed, the vertical arm of the connecting L is turned down to a horizontal position, which permits the liquid to drain into the washing compartment and thence out through the waste pipe of the latter.

The acid blast and the mechanism for its application have been patented in this country and abroad.

ELECTRICAL SECTION.

"Railroad" Meeting, March 28, 1899.

SOME OF THE LARGER TRANSPORTATION PROBLEMS IN CITIES.

BY EDWARD E. HIGGINS.

[*Concluded from p. 327.*]

THE PROBLEM OF CARS AND CAR SERVICE.

Upon the character of the cars and the car service of a street railroad depends largely the gross revenue which will be derived from the public. One of the keynotes to success in handling street railway property is to bring about to the greatest possible extent "short-distance riding." The

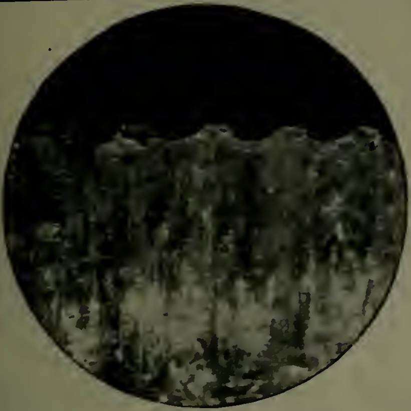


Fig. 1.—Immersion method, one etch, 4 minutes.

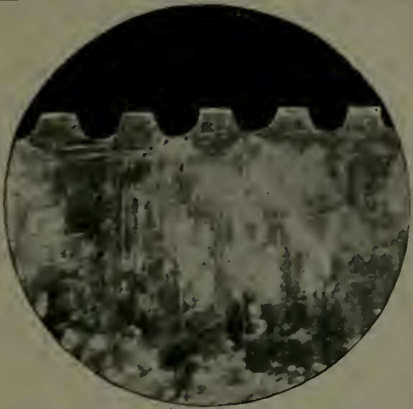


Fig. 2.—Blast method, one etch, 4 minutes.

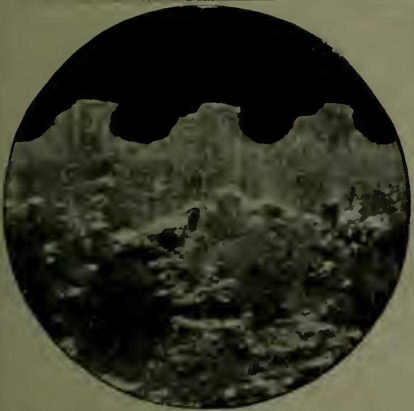


Fig. 3.—Immersion method, two etches; first etch 4 minutes, then powdered against right wall of depression, then second etch of 6 minutes.

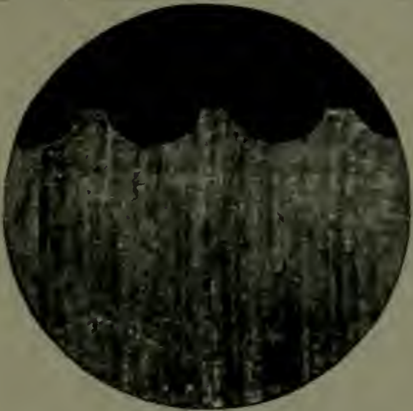


Fig. 4.—Blast method, one etch, 4 minutes.

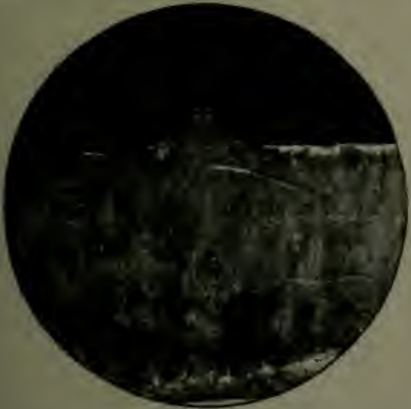


Fig. 5.—Immersion method, isolated line, one etch, 8 minutes.

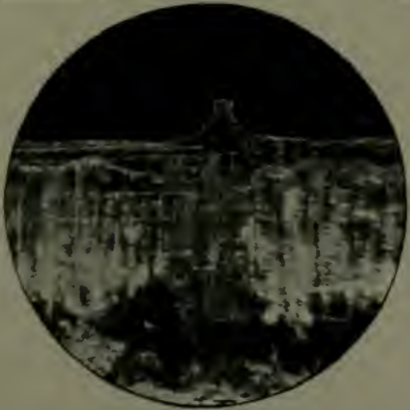


Fig. 6.—Blast method; isolated line, one etch, 4 minutes.

LEVYTYPE , ENGRAVERS AND PRINTERS, PHILADELPHIA

Sections of Zinc Plates, magnified 24 diameters, showing comparative effects of etching by Immersion and by Blast Process. Reagent, Nitric acid, 10° Beaumé.

with cross seats were in almost universal use, though many railways denied themselves and the public the luxury of the open cars. To-day cars range in length from 20 to 40 feet, and a 16-foot car looks almost as small and as much out of place as the old 10-foot and 12-foot cars of the horse railway era. With these longer cars has come greater steadiness in riding, and trucks have been greatly improved to the end of bringing this about. The West, always in advance of the East in obtaining beauty and convenience in railroad passenger trains, is somewhat in advance of the East also in street railway cars, and in St. Louis, Milwaukee, Denver, San Francisco and elsewhere, will be found some of the most beautiful travel-attracting street cars in the world, with cross seats, center aisles, broad windows, window-guards, electric signals, and elegant fittings throughout.

Somewhat strangely perhaps, the almost universal foreign custom of providing roof seats on tramway cars has not been popular in this country, the reason appearing to be that such cars are better adapted for slow speeds than for high, and for countries whose peoples do not place upon time the same value that Americans do, for there is no question that it would be impossible to keep up the present schedule speeds on American street railroads if the cars were obliged to take time to load and unload passengers to and from the roof seats, while the danger of accident to people not used to climbing up and down the stairs while cars are in rapid motion would be considerable.

The manager or employé who lays out the schedules of a street railway has in his hand when doing this work the operating profits of the enterprise. If he is too niggardly with car mileage, he saves a little in expenses, but may perhaps reduce gross income by a far greater sum than the savings. If, on the contrary, he is extravagant with car mileage, he may increase expenses far more than income. The mean is, indeed, a golden one and worth a never-ending series of experiments to determine the maximum traffic and profit that can possibly be derived from any given line. In more than one instance, a languishing or unprofitable enterprise has been turned into a vigorous and profitable one by the mere application of common-sense principles to the car service.

THE PROBLEM OF TRACK AND ROADBED.

The introduction of longer and heavier cars, a much more frequent service and a self-propelling power which needs to obtain a grip on the rails, have enormously increased the difficulties of the track problem for street railway companies, and on all sides are being heard complaints that joints are wearing out, rails are showing excessive wear in spots, leading to unevenness of track, and that the repairs and depreciation of roadbed for electric traction have been underestimated. The most heavily worked track and special work of the larger cities will stand hardly three years of service, and the life of electric track varies from this period to ten or twelve years as a maximum, according to our present experience. When it is stated that it costs from $10,000 to $25,000 a mile to replace track, it can easily be seen how serious is this problem, and how great a burden upon the finances of a company is the track repair and depreciation account. In the few places where street railway profits seem excessive, therefore, such burdens as these, which are yet, in all their seriousness, of the immediate future rather than of the present, should be remembered.

THE PROBLEM OF FARES.

In this country a uniform 5-cent fare is almost universal; in other countries a variable fare, based on distance traveled, is equally universal. There is something more than a mere financial policy involved in the discussion of the fare problem. Broadly speaking, a uniform fare means depopulation of the tenement-house districts and settlement of the suburbs—means a clear happy life in purer air and better surroundings—means individual homes and plenty of room for the children. A graded fare means enormous density of population in the heart of the city, scanty suburban settlements, pale faces, sickly children and a miserable home-life for the masses. These words are not too strong, nor is the influence of street railway fares upon these living conditions exaggerated. The difference between the street railway track mileage and investment in our principal cities and those of equal size abroad is something amazing. Compare, for example, Brooklyn, Glasgow and Boston, three cities of about the same size. Brooklyn with a population of about 900,000, within 5-cent fare limits, has over 500 miles of track; Boston, with 700,000 population, has 325 miles of track, while Glasgow, with 800,000 population has but 77 miles of track. The total street railway investment in Brooklyn is nearly $100,000,000, in Boston is over $25,000,000, and in Glasgow less than $4,000,000. The 800,000 people of Glasgow are distributed over but 23 square miles, Brooklyn's 900,000 inhabitants live in a 45-mile area, and have a population density of but 25,000 per square mile, while Boston's 700,000 inhabitants are happy in 122 square miles of area, with a population density of but 5,700 per square mile. Is not the uniform fare principle justified by these figures alone?

For 5 cents a citizen of Brooklyn may travel more than 10 miles. A citizen of any of our great cities can travel 10, 15 or even 20 miles. In doing so he inflicts a loss upon the company, and if there were a large proportion of the total number of passengers carried who traveled so far, or even 5 or 10 mile distances, our city railway properties would be continually unprofitable and probably insolvent. It is in the short distance riding that the losses are made up, and it must, therefore; in frankness be admitted that the short distance rider pays part of the fare of him who rides the longer distance. This is an apparent injustice, which cannot, however, be remedied unless the whole principle and policy of American street railroading be radically changed, and the effect of the change would be undoubtedly disastrous from a sociological point of view, tending to check the expansion of cities into the suburbs and increase the congestion of life in the centers.

Is the present 5-cent fare too high, and can it be reduced without consequent disasters to street railway companies? Both these questions can be most emphatically answered in the negative. The street railway companies of to-day are giving to their patrons a maximum ride two or three times greater than that given for the same price ten years ago, and an average ride at least 50 per cent. greater; they are giving them a speed in transit from 50 to 100 per cent. greater; and are providing them with cars, cleaner, finer, better lighted, and in all respects superior to the old régime. Is a mere change of motive-power from horses to electricity a magical thing that can multiply wealth as by a philosopher's stone and make all things possible? No. The street railway companies of the country are by no means unduly prosperous to-day. In fact, too many of them are struggling under far heavier burdens than ever ought to have been put upon them by the people. In Philadelphia, for example, the right to change the motive-power from horses to electricity has been granted on condition that the street railway company shall lay down new pavement and permanently maintain this pavement on over 400 miles of street within the city limits—a condition more enormous perhaps than that ever before laid upon a quasi-public industry, and one which will make the payment of excessive dividends or a reduction of fares impossible for many years to come, if not forever. Take twenty of the great street railway properties of the country, none earning less than $1,000,000 gross per annum. Their aggregate capitalization in bonds and stock outstanding is nearly $500,000,000; their aggregate gross receipts are about $67,000,000; their apparent operating expenses (including taxes) are about $42,000,000, or 63 per cent. of the gross receipts; and the percentage of apparent earnings from operation amount to barely 5 per cent. on the total capitalization.

"But these properties are overcapitalized," it will be said.

Admitted.

Suppose I assume, too, for the sake of the argument, that the overcapitalization is 100 per cent., that the real accumulated cash investment in all these particular properties is not $500,000,000, but $250,000,000. This certainly would seem to be an assumption sufficiently sweeping to suit any critics, and is far larger than the fact.

As a result, we have apparent net earnings equivalent to a return upon investment of 10 instead of 5 per cent. Is this larger figure too great for risks so serious as those which have to be taken by investors in street railway properties?

But this is not all. These twenty properties are not now in reality earning 5 per cent. on their $500,000,000 of their capital liabilities, or 10 per cent. on half this amount. They are knowingly or unknowingly deceiving themselves in the matter of maintenance, and some day there will be a reckoning in consequence. In other words, their percentage of operating expenses to gross receipts is much more than 63 per cent., and perhaps hardly less than 75 per cent., and they are probably earning on an average but 4 per cent. or less on their capitalization.

THE PROBLEM OF TRANSFERS.

To most people, no doubt, the transfer problem appears a very simple one. Surely it would seem that no more just and reasonable demand could be made on a street railway management than that a passenger should be allowed to ride from any point within a city to any other for a single fare, particularly if the entire system is owned by one company and if the city is a small one. It is on deeper investigation only that the real difficulties appear. Broadly speaking, it may be said quite certainly that hardly a street railway manager in the country would object to the simple proposition outlined above if that were all there were to the problem. It is not of serious importance to him whether a passenger complete his ride on the original car or on a connecting one. The trouble is found in limiting the use of transfers to their entirely legitimate purpose without running against sheer dishonesty on the part of the public and on that of the company's own employés. The entire transfer problem is one of preventing this dishonesty and of nothing else. To prevent conductors from replacing cash fares with transfers is possible only by the most careful comparison of returns and records in connection with a more or less complete detective force, and the cost of this combined service is often very large. But a more serious trouble than this by far is found in the "swapping" of transfers by, for example, clerks in the same offices living in different parts of the city, or by their improper use in other ways for return or continuation trips, and in the actual giving away or selling of transfers taken for that purpose at the close of the honest trip. There are not a few cities in which the routes are so peculiarly laid out as to make it practically impossible to put into effect a transfer system which cannot be thus tampered with to a most serious extent, while in all cities there is a more or less large percentage loss from illegitimate use. The fact that in nearly all cities of America the street railroad companies have conceded some form of transfer accommodation, and are standing the consequent loss in receipts and in operating expenses, should be credited to them as a partial offset for some of the things which they have been obliged to refuse the public.

THE AVOIDANCE OF ACCIDENTS.

In the operation of many cars through crowded streets of cities, it is inevitable that there should be accidents, trivial and serious, from the running down of a peddler's cart to the killing and maiming of a carload of passengers. The fact that the trivial accidents are so few and the serious ones so extremely rare in proportion to the number of passengers carried, and to the number of obstructions, human and otherwise, in the streets, points to the remarkable care which is uniformly exercised by the employés of our great companies working under carefully established rules. During the year ending September 30, 1897, the street railway cars of the entire State of Massachusetts ran 61,577,917 miles, and carried 308,684,224 passengers. The number of accidents of all kinds was so extremely small that the cars traveled on an average over 48,000 miles before injuring a passenger, and about 83,000 miles before injuring any one in the streets or highways through which they passed. The number of fatal injuries was only one for each 200,000 miles traveled. The number of fatal injuries to passengers was but one for each 30,000,000 carried. This is a marvelous record considering the character of the "rights of way" which street railways possess, and indicates the most careful attention to safety in travel.

Accidents may be minimized in number, (1) by reducing speeds of cars indefinitely; (2) by increasing braking power; (3) by the introduction of some form of fender or protective device; (4) by the selection of employés who will exercise care in the handling of cars; and (5) by the education of the public itself to treat the cars with respect at all times. Speeds will increase rather than decrease, for the constant effort is and will be, in America, at least, to save time at the expense of concurrent disadvantages such as even that of injuries to passengers and wayfarers, and if the proportions do not rise to extraordinary figures, the public will not suffer the carelessness or misfortune of the very few to interfere with the advantage of the immensely greater number. The remedy must be sought, therefore, in the other directions named, and will, as a matter of fact, be found in the combination of all. The public, whether on foot or in vehicles, is daily learning to keep out of the way of street cars, and the lesson of true economy of good employés has been well learned by street railway companies. No entirely satisfactory braking system of general application has yet been found, but the power of mechanical brakes has been enormously increased since the advent of electricity, while air- and electric-brakes for the higher speeds of interurban work have been developed, not perhaps to the highest point possible to reach in the future, but to one of present commercial and effective value. Fenders are yet a necessity, though a troublesome one, and it is hard to see how their use can be avoided even with the best braking appliances.

THE MANAGEMENT OF EMPLOYÉS.

It is within the power of the street railway manager to exert an influence for good or for evil—towards better things or worse—in the lives of hundreds or thousands of employés. He can arrange their hours so as to keep them constantly on the move between home and work, or so as to give them long free periods of time within desirable hours. He can harass them with a multitude of rules, or deal with them as reasonable beings with comparatively few rules. He can make them loyal and enthusiastic in the service of the company, or disloyal and indifferent to its interests. Upon his treatment of employés depends the success of his administration more than upon any other of its features.

The new street railroading of to-day has brought into service a much more intelligent grade of employés than was found in old horse-car days. Then it was only necessary that a driver should be able to handle horses with reasonable care and to maintain the schedules through the streets. The conductor was watched with the most jealous care to prevent dishonesty. Uniforms were rarely seen, and the morale of the men was undeniably poor.

To-day, the entire force of employés, particularly in the transportation department, is composed of trained men, neatly uniformed and with quick and intelligent minds. They are and must be smart, "snappy" and businesslike in the conduct of their work. The conductors and motormen must know many things about their cars, which were never required from the horse-car force, since blockades must be prevented and the road kept in operation at all hazards. As a consequence, the present employés can be made to feel proud of their work and their opportunities. The organization is more complicated, the chances for promotion are better, and the conditions are in all respects improved. The most successful managers of to-day have put their systems far beyond the danger of strikes by making friends with their men, and putting certain influences into play among them, which enormously increase their *esprit de corps*.

The most important of these influences perhaps is that of increase of pay with length of service. In the old days, the wages of a conductor or driver were no greater to the man of twenty years' service than to the six months' fledgling. All were treated alike, the theory being that the *work* was the essential thing, not the *man*. As a consequence, disaffection was easy to create in a body of employés.

The long service employé felt, indistinctly perhaps, but none the less certainly, the injustice of putting him on a level with the new man, and felt, too, that there was nothing for him to look forward to in the future. All men were equal in the labor meetings, and a knot of the disaffected could sway the entire body of employés.

It is easy to understand the restraining influence brought about by the adoption of a graduated wage scale in a body of employés of this character. Suppose, for example, that this scale runs from $1.75 to $2.25 per day, the minimum being received for the first year's service, and a 5-cent per day increase being granted for each subsequent year, so that only after ten years' service will the $2.25 rate be obtained. We have, therefore, in such a force ten different bodies of men, each growing better and better satisfied, and more and more conservative as the years go by. Each takes a pride and pleasure in every increase of pay, looks forward to still better things, and considers the entire wage scheme reasonable and just. The chances for disaffection are confined to the newer men and the influence of all the others is a restraining one not only because of their self-interest, but also because of their longer experience with the company's methods and the consequent value of their advice. In the remote contingency of a threatened strike, the employés cannot go before the public with as strong a case as they could were the average wage rate $1.75 or $2, for example, since the company can show that it is really paying the higher wages demanded for experience and ability, and it is the new and untried men who are making the trouble.

Another influence of much the same general character is the adoption of the "service stripe" plan of recognizing length of service. The man who carries on his sleeve one, two, three or four stripes, signifying an equal number of years of service, or one or more gold stripes, signifying five years each, feels the responsibility of his position, and feels a self-respect which shows immediately in his care of the traveling public, and which in turn commands respect from that public. He is identified with the company, its interests are his and will be guarded. The officers of the company themselves should have, and do have, as a matter of fact, great respect for the older employés, and the entire force, from the president down, is welded together more and more closely as the proportion of the long service men increases.

Still another good influence among the men is that of promotion to positions of higher responsibility, and the sooner street railway companies realize this and put the principle into practice, the better will be the results they obtain, and the more nearly will they approach the stability and strength which the railroad industry has gained by the security in tenure of office and chance of promotion which has been for many years granted to railroad employés.

The principle of competition in the conduct of the street railway business has not as yet been introduced to nearly the extent that its value warrants. In the maintenance department, for example, piece-work as against time-work could probably be adopted with considerable advantage. A man will always work harder and more intelligently and adopt better labor-saving methods if the fruits of his work are to be given him in greater remuneration, and while careful inspection of such work is of course necessary, the conditions under which street railway repairs are carried out are such as to make such inspection feasible and efficient. The experiment has been made in one or two cases with excellent results.

Another place where the competitive idea can be introduced is in the management of the power used by cars. It is well known that motormen, as a rule, waste power enormously by the improper handling of controllers. In many cases this is done carelessly, without much thought of results. In others it comes from a disposition to play with the immense force at the command of the motorman by the movement of his hand. The results of this misuse of the controller are seen not only in the power cost, but also in increased depreciation of motors through constant use of excessive currents. Now the very simple plan of placing in each car a wattmeter to measure the power which is used by that car, and of taking regular readings of this wattmeter at the end of each run, has accomplished in one or more instances, and would accomplish in practically all, remarkable results in the saving of power and depreciation, for the moment that a motorman is called to account for using more power in going over a route than another motorman uses, that moment he begins to be more careful. In one case recently made public, a saving of 33 per cent. in the cost of power was effected by this simple method.

The street railway employés' associations, with their corresponding club rooms, gymnasiums, baths, libraries, and monthly and annual entertainments, together with the provisions for death benefits, etc., tend to bring the management and the men into closer union, and are always to be encouraged as valuable adjuncts to the regular work. The library feature, which has been lately introduced on at least one large system, brings the home influence into play in behalf of a management, tending, however slightly, to cause the women of the family to exercise a restraining influence over the men in times of threatened strikes.

Broadly speaking, the modern street railway management, as distinguished from the older forms, brings men into closer communion with the official staff and creates in them a self-respect and manliness of character which is the best possible security against trouble. Those managers who have adopted these broad-gauge methods and have been genuinely solicitous for the well-being of their men, have been successful to a remarkable degree in securing the personal loyalty of the latter and in strengthening their own position and that of their company in the community.

THE ADVANTAGE OF COMBINATION.

The public gains, or ought to gain, with combination of municipal service enterprises. No principle in practical sociology is better established, perhaps, than that which grants to public service industries in municipalities the right to be regarded as "natural monopolies." It can never be to the permanent advantage of the people to have two lines of street railway serving the same territory on the same or parallel streets, while it is a distinct disadvantage to have separate companies serving different sections of the city. A transfer system between independent companies is an impossibility on any fair basis, while the almost universal result of a consolidation of several different companies in a single city is the immediate granting of transfer rights, and an immense saving to the people. This one advantage alone is a sufficient *raison d'etre* for consolidation, but in addition to this there are others. The entire transportation of a city can be operated by a single company on broader lines and to the far better service of the people than can be done by two companies. Economies can be introduced and more liberal expenditures in other directions made possible, through routes can be established along the lines of customary travel, and in many other ways the people will be benefited.

The economies effected in the street railway administration are numerous. Instead of several power stations one or two of the best ones only may be kept in service and the cost of generating and distributing the current may be minimized. A better service may be given with a smaller number of cars than before, the official salary list may be reduced, the principle of division of labor may be introduced into shops, repair force, etc., and the day when fares may be made lower to the people will be brought distinctly nearer.

There is also much to be said in favor of the consolidation of street railway and electric light and power interests. The great difficulty with electric lighting stations to-day—a difficulty which is keeping up the price of light and power to materially higher figures than ought to be possible of attainment—is the fact that the stations can be loaded up to their capacity for but a few hours out of the twenty-four. This puts the working forces to a disadvantage, leaving them comparatively idle for many hours, and reduces the economy of the engine or leaves a part of the plant idle, which thereby earns no interest upon its cost. If the market for power can be increased and the loads distributed fairly evenly over the day, the cost per unit of power delivered will be far less than at present, and the price can be correspondingly reduced. The consolidation of all electric power-using interests will tend to bring about this result, and is, therefore, to be favored on the grounds of public as well as on private gain.

THE PROBLEM OF MAKING A FAIR BARGAIN WITH THE CITY.

I have purposely left this most important problem till the last, because it is only through a more or less clear understanding of the nature of the other problems hereinbefore discussed that the true character and difficulties of this one can best be understood. There are, and will unfortunately continue to be, a great many false theories and ill-advised schemes put forward to solve the problem of how to best handle municipal service enterprises and to relieve the tension now existing between municipalities and private companies. The truth is that there is no one method of universal application. It is as foolish to assert that municipal ownership of everything in sight will bring the millennium immediately as it is to hold that municipal ownership has no place whatever in the management of public service enterprises. There is a sharp distinction between that class of services which a city has to itself use in whole or in part, such as, for example, sewerage, water-supply, gas or electric light, etc., and that class which it does not use, such as transportation. An attempt to control the former class may be defended on the ground of wise economy in city expenditures. An attempt to control the latter has for its basic purpose an idea either of obtaining revenue by indirect taxation or of giving a service to the people at actual cost.

Under all circumstances and with all kinds of enterprises, it is true that municipal corporations in which responsibility for results is so greatly subdivided cannot theoretically, and do not, historically, conduct business enterprises with economy or efficiency, while even more important than the question of mere money-saving or waste comes the undeniable fact that the trustees of municipal funds cannot possibly manage those funds on broad lines, or with the calm confidence in the future justification of present expenditure that private capital would have. The taxpayer would not suffer the imposition of present burdens for the benefit of posterity, at least without a storm of criticism which would render the position of the trustees difficult or untenable.

The transportation enterprise, particularly, is one where investment must be made without regard for present profit if the growth of the city on right lines is to be kept up. For this reason, and entirely independent of the mere question of possible revenue to be derived by a city from the operation of its street railway system, I believe firmly that it would be utterly unwise to place the control of a city's transportation agency in other than private hands. I believe that in practically all cases the true solution of the problem of relations between a city and its street railway system is found in granting to the latter private ownership and operation, complete monopoly, perpetual franchises and a system of perpetual profit-sharing with the municipality, joined to a remission of charges to the public if and whenever profits come to be sufficient for that purpose.

By a policy of this kind it is possible—

(1) To avoid pledging the city's credit for making the necessary original investment.

(2) To place upon private capital the burden of all losses realized or contingent.

(3) To obtain for the city an equitable share of all profits actually realized.

(4) To avoid the creation by the city of a complex bureaucratic organization with its attendant political dangers.

(5) To secure for the benefit of the municipality, its people and the private capital invested the undeniable benefits of private management as affecting profits, perfection of service and direct responsibility.

(6) To secure for the municipality, the people and the private capital invested the true pro rata shares of each in the additional profits coming with municipal development in the future.

When all the safeguards possible to devise shall be thrown around a municipal contract of this character, it will be found that the street railway problem in that particular city is solved for all time, and in a fair and equitable manner. Thenceforward the municipal government and the street railway corporations will work *together* to build up and develop on its broadest lines the municipality of whose interests they are at once guardians and servants.

"Railroad" Meeting, March 28, 1899.

THE ELECTRICAL INSPECTION OF STREET-CAR EQUIPMENTS.

By Albert B. Herrick,
Consulting Electrical Engineer.

As electrical machinery is becoming such an important factor in modern civilization, the maintaining of this machinery requires indirect methods in order to make visible, through the means of instruments, the electrical conditions of the apparatus or machinery.

Nowhere in the application of electricity is the electrical inspection more necessary than in street-railway equipments; here the motor is operated with exposures to weather, mechanical jars, heating, and severe electrical and mechanical strains; and the predictions were when the first roads were operated, that this system was impracticable, and a preposterous engineering proposition.

The development of accurate methods for finding these hidden electrical troubles in an equipment has been urged upon me, for the reason of the high cost of the electrical repairs on street-car equipments. These aggregate many million dollars per annum in the United States; and to bring this forcibly to your minds, in two of the roads which I have examined, I have found the cost of the electrical repairs of a 22-foot double equipment to cost the same as those of an 80-ton locomotive on the Pennsylvania Railroad, the same distance, and carrying a full train of freight cars.

The wiring of a car by which the current is conducted through the equipment is of necessity not a fixed nor rigid system. The resistances which are used to control the flow of current through the equipment, on account of their limited weight and space, will not carry the current continuously, and careless motormen may injure the resistance by improper handling of the controller.

The controller, which is practically the nerve center of the equipment, reflects in its depreciation all the latent defects in the equipment.

After carefully inspecting, electrically, a large number of equipments, one feels very much like diagnosing the different diseases which are inherent in the various equipments, and also separating from these, those diseases which are developed by forcing or the improper handling of the controller, which are attributable to poor motormen.

There is another class of diseases which have their origin in careless inspection and careless maintenance of the equipment.

It is not so much my intention to analyze the diseases to-night, as to describe the means by which they are detected and located.

Following out our original anatomical idea, it is easiest to look at the various ramifications of the current flowing through the equipment as a circulating system, with the controller as a deflector for these different circuits through the equipment. *Fig. 1* shows a very common form of series parallel controller with the connections it makes with the apparatus on the first notch; with each movement of the controller handle the current is changed in its path. The sequence of changes made by the controller as it passes from the first position to the last, including nine positions, in this case, is as follows: The first position starts the current flowing through the electrical circuits of the car, and the car should now move. A large amount of energy is lost in the resistances R_1, R_2, R_3, R_4, which choke down the initial current on the motors. From the first step to the second, cuts out 4½ ohms in a standard equipment of this type; from the second to the third step cuts out 1½ ohms, and from the third to the fourth step cuts out ½ ohm.

The motors are both in series and across the full potential between the trolley-wire and the ground. The rheostat, which is the resistance, that has just been cut out by the first three steps of the controller, after it has been installed on the car, is given very little attention; it generally increases in resistance with age. I have found many rheostats over four times the resistance they should have been when new. The result of this increase in resistance is that the car will not start on the first step of the controller when the resistance is hot, or the car heavily loaded; for the resistance is so high on this step that the current is cut down below starting value; and when the second step on the controller is reached, the car will have what is known as the "kangaroo start." The reflection of this defect in the equipment is to increase the temperature of the motors, increase the strains on the motor, and increase the current demand on the station, and give a disagreeable acceleration to the car. This defect is more noticeable on those motors having a large starting torque. The motors which have a small starting torque do not show this defect so much in the start and car acceleration, but struggle along under this excessive condition until they retire to the repair-shop, damaged.

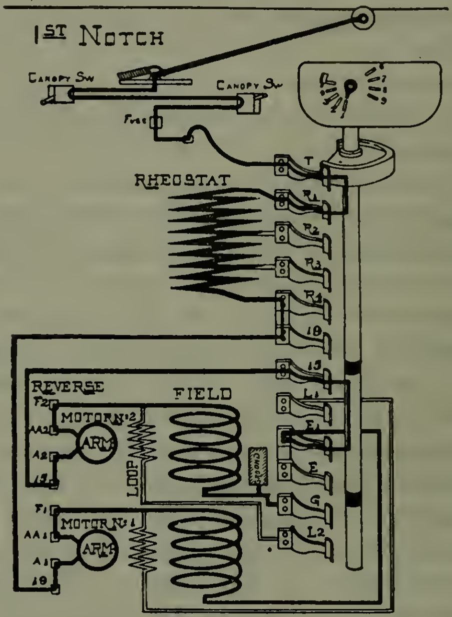


FIG. 1.

I have expanded on this point somewhat, because it does not seem to be generally known that this condition is primarily the cause of a large number of break-downs in equipments, which condition may be caused by burnt-open or high resistance in rheostats. A low resistance on the first step of the rheostat has identically the same effect on the equipment as the first step being too high, and the second step being normal. Where repair accounts were kept against individual cars in street-railway operation, I have often found the high cost of repairs on some cars due to just this rheostat trouble; the controller, armature and fields being continually repaired, while the rheostat, which is the real cause of the trouble, is left unmolested.

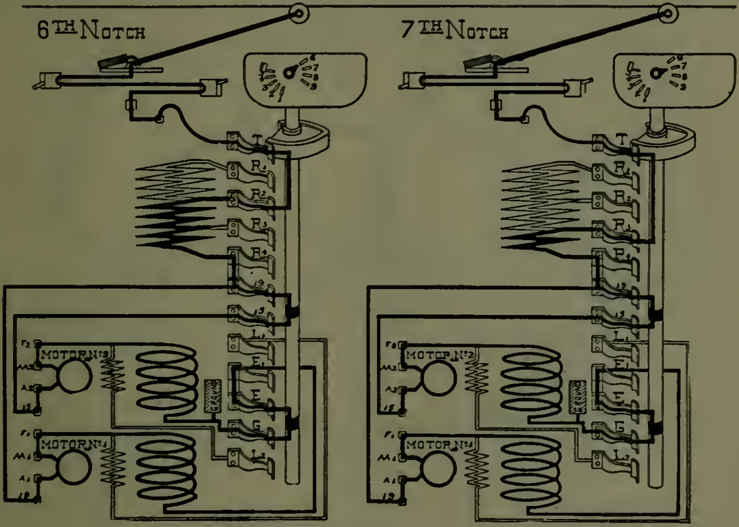


FIG. 2.

Rheostats are also much more heavily strained on roads possessing considerable grade, and they tend to increase in resistance and prevent the most effective operation of the equipment; and this condition increases materially the watts per car-mile required on grades where starts are frequent.

In the type of controller under consideration, the resistance between the second and third steps, R_2 and R_3, being high, is not of much importance in this part of the operation of the controller, if it is not so high that the car loses acceleration; but if we follow the operation of the controller in *Fig. 2*, you will notice that on the sixth notch in this position the motors are connected in multiple; and this second to third step in resistance is again cut in series with the two motors in multiple. Here, if the second step is high, the equipment will lose acceleration, and when arriving on the seventh notch, the motors will again be subjected to an abnormal flow of current.

It is evident that these conditions can only be determined by the direct measurement of the resistances of

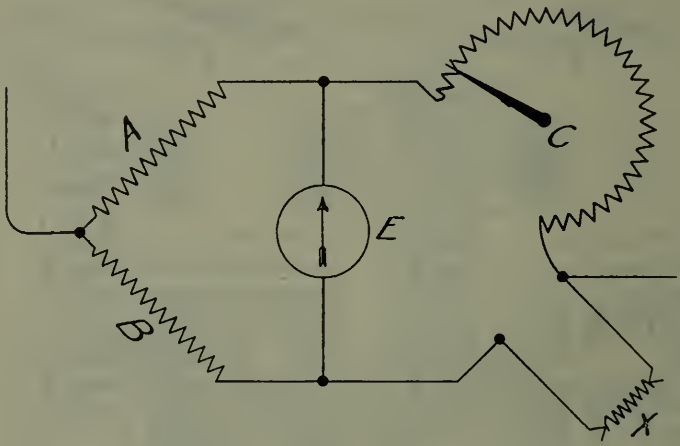


FIG. 3.

these circuits as made by the controller; but the resistances of these circuits possess peculiar features which are not common to a purely metallic circuit. We find contact resistances in the controller and carbon-brush resistances in the motor. The contacts give extremely variable and unreliable results when measured with a low-potential test current. The carbon-brush contact will often appear as an insulator under this condition, and a poor controller contact will give a constantly varying resistance.

In order to bring the contact resistances down to normal, it is necessary to pass considerable current through the equipment when testing, and it is most convenient to obtain the current from the railway circuit. But when we use a current varying as the ordinary railway current varies, and yet discover the variation of resistance as low as ·005 of an ohm, another difficulty confronts us, and neither a bridge method nor fall of potential method are applicable to this work.

In any bridge method the measurement of a resistance also includes the contact resistances by which this resistance is placed in the measuring circuit, as at *Fig. 3*, and due to this varying quantity introduced into the bridge method, it is not a reliable instrument under $\frac{1}{10}$ of an ohm; nor in the other extreme, can the bridge give quantitative results over 500,000 ohms. For these reasons it is useless in measuring low resistances with any degree of accuracy which will admit of a definite analysis, especially in those resistances met with in fields and armatures. No multiplying arrangement can increase the accuracy of any measurement external to this instrument.

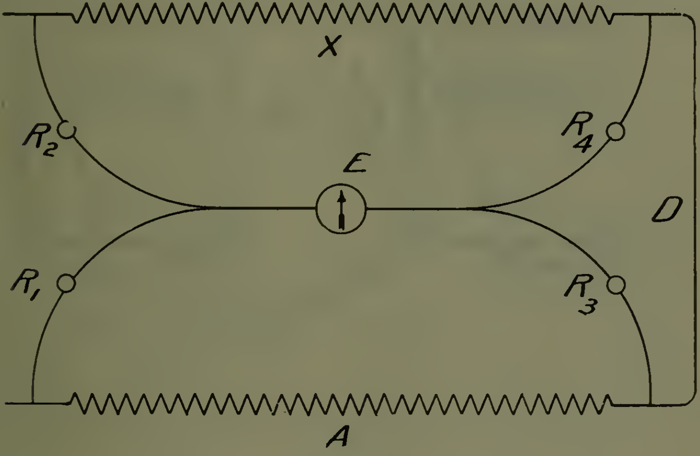


FIG. 4.

Thompson's method of measuring resistances which is applicable to low resistances, is extremely delicate and of general use for this purpose; but there is one very important condition necessary in using this method; that is, there cannot be any appreciable resistance between standard *A* and the resistance X under measurement, as at D in *Fig. 4;* for in that condition there would be considerable fall of potential along the measuring lines, which will interfere with the accurate comparisons of the resistances, A and X, under measurement, and in car inspection it is impossible to have the standard and resistance under measurement adjacent to each other. The volt-meter and ampere-meter method, where connected as at *Fig. 5*, will give the resistance sought, by dividing the volts read by the amperes flowing. But in measuring an inductive circuit, such as a field or armature of a motor, we find that with the voltage falling, the resistance between any inductive terminals is apparently

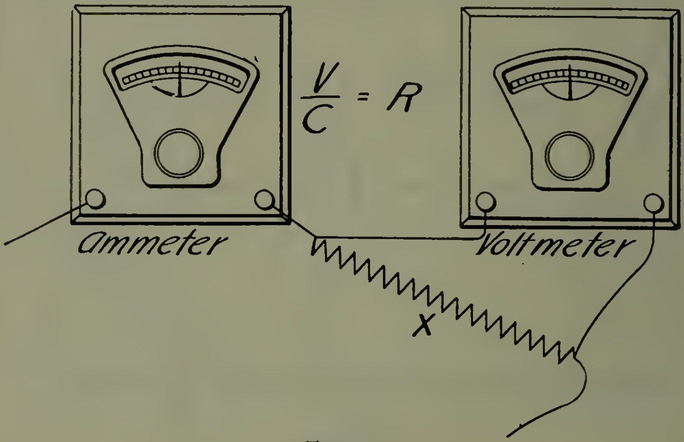


FIG. 5.

lower than its true resistance; and with the potential rising, the resistance will be apparently higher than the true resistance measured. This method is too tedious and unreliable for the purpose of accurately diagnosing equipment troubles, as, to use this method, we have to balance our circuits inductively as well as ohmically in using the trolley circuit in equipment testing; but to make all this practical and of general utility, the system must be so devised that the measurements and determinations can be made quickly, and not necessarily by one skilled in the art.

The author, after years of experience, has had to abandon the above methods, for they did not produce sufficiently concordant results to make the analysis of an equipment positive, and he has developed the differential method shown in *Fig. 6.* This is nothing more than separating the differential coils of Kelvin's method, electrically, so the resistance between *A* and *X* would not interfere with the accurate comparison of two resistances.

Another condition necessary in the development of a system is the keeping independent from each other the different tests requiring different connections made to the testing apparatus, so an inter-locking system had to be devised by which means the test under consideration could be connected up only when the dial was turned so the pointer was opposite that test, then the holes for inserting the plugs in this test registered with the proper receptacles, and the plugs could be inserted for this test, and no interconnections could be made which would injure the instruments used in these tests.

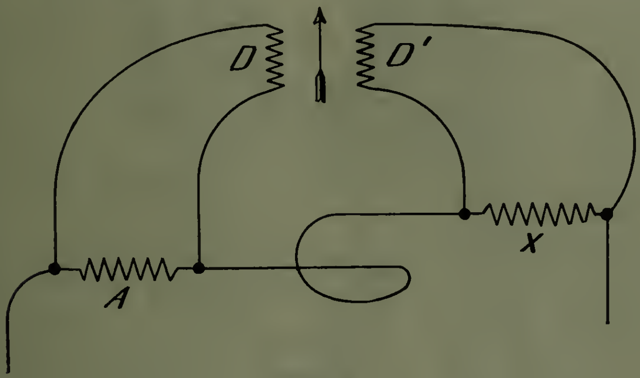


FIG. 6.

The semi-portable apparatus, known as *Form D*, is shown here in *Fig.* 7, which combines besides the inspection tests, all other well-known ampere-meter and volt-meter tests which are required on the line, car operation and electrolysis. The testing set, including only the inspector's test, is a much more portable affair, and can be readily carried from car to car. It is very easy to make an electrical inspection of an equipment in one minute, when proper arrangements are made to expedite the test; and a testing set can be taken to any part of the road where the cars can

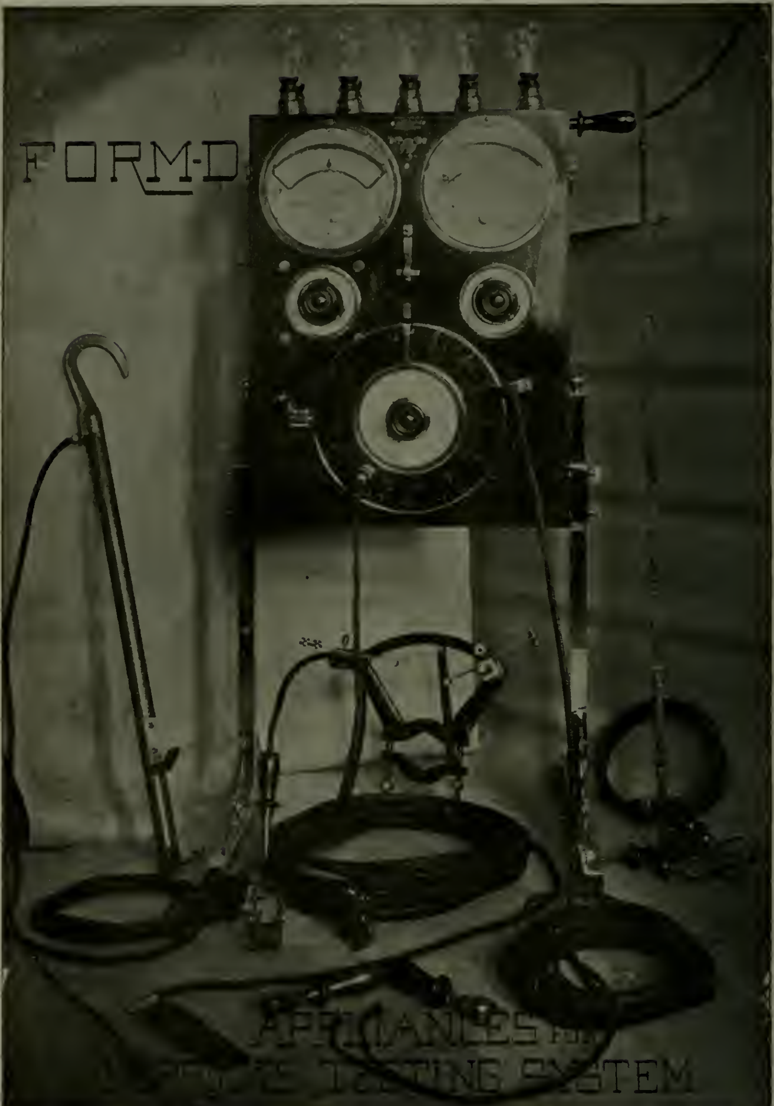


FIG. 7.

be delayed, and this test can be made on each car by holding it for one minute.

The inspection test consists simply of measuring the equipment up on each notch of the controller, and every road fixes its maximum and minimum standard for each type of equipment, there being considerable range between the allowable maximum and minimum at first.

To maintain an equipment means to keep the different controller points within standard values, and any part which departs from standard value can be immediately repaired at small cost before the more serious secondary effects have rendered the equipment a cripple.

I show a plotted curve (*Fig. 8*) of ten identical equipments which were inspected on a fairly well operated road, and it shows quite a variation in rheostats, and also two burnt-out fields and a poor brush holder. A straight line is drawn through these tests in order to show where the standard should be. It will be noticed that there are high rheostats in several equipments, and it will also be noticed that in equipment No. 23 the high rheostat has resulted in the burning of the field of No. 1 motor. It will cost five times the amount to replace the field that it would to repair the rheostat, and it is only by careful inspection that these primary troubles can be detected in time to prevent a more serious loss.

The ageing effect on the different types of equipments tend to lower in some and to raise in others the resistance of the rheostat. The field resistance will fall slightly, owing to the annealing effect on the wire, but if the resistance falls below 1 per cent., it is due to turns being short, or the carbonizing of the wire insulation known as baked, which allows the current to pass between the adjacent turns through the carbonized cotton insulator instead of around the turn to produce the magnetic effect on the field.

The result of this is to make the armature revolve faster in the weakened field, and the armature will become overloaded in its effort to run the car, and also to carry the other motor; in this way if the equipment is operated the result will be an armature burnt out.

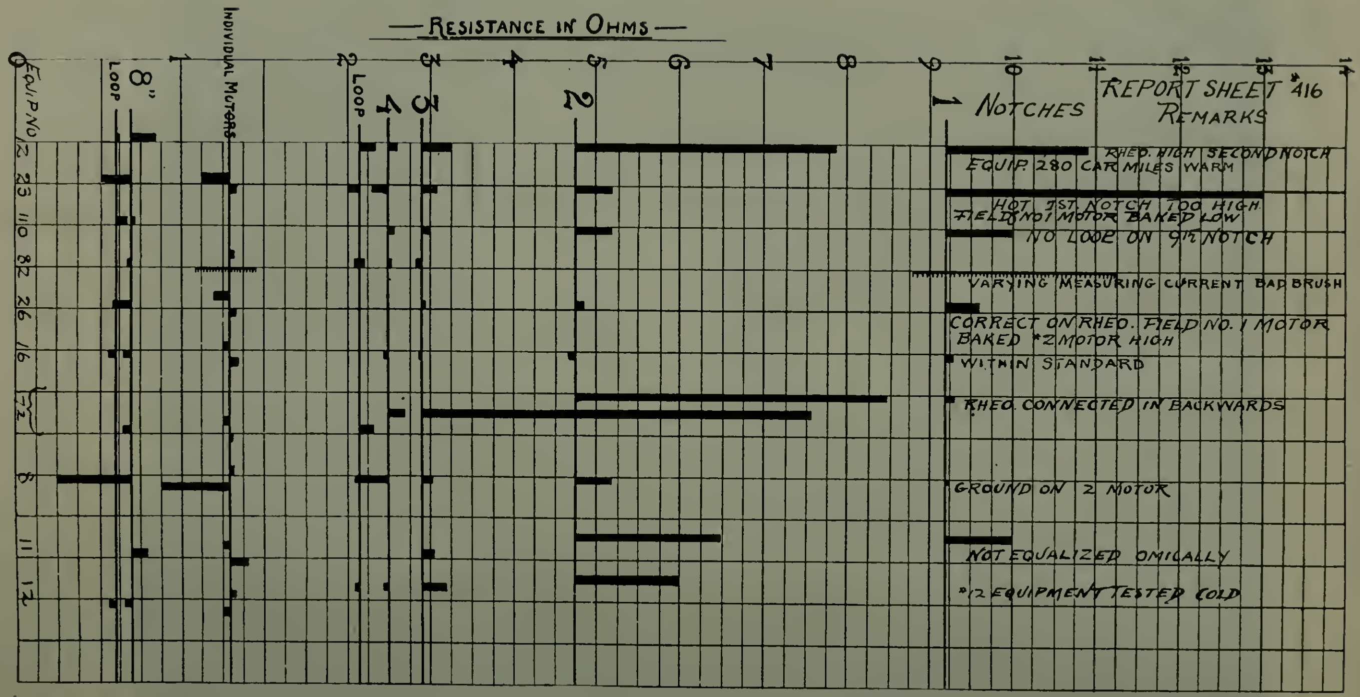

—Resistance in Ohms—
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Report Sheet #416
Notches
Remarks
1
2
3
4
Loop
Individual Motors
8"
Loop
Equip. No
12
23
110
82
26
16
72
8
11
12
Rheo. high second notch
Equip. 280 car miles warm
Hot 1st. notch too high.
Field No 1 motor baked low
No loop on 9th notch
Varying measuring current bad brush
Correct on rheo. Field No. 1 motor
baked *2 motor high
Within standard
Rheo. connected in backwards
Ground on 2 motor
Not equalized ohmically
*12 equipment tested cold

Fig. 8.

In one case in which I inspected the cars, the armature winder, who was an excellent worker, had been discharged for the reason that his armatures would not run more than a few hundred miles before being burnt out. I found that defective fields were the cause, and after replacing the bad fields in these equipments, the armature winder was reinstated, and there has been no trouble since.

An undiscovered baked-out field is one of the most prevalent causes of motor troubles. A number of methods of winding and treating fields are now in use, which have for their purpose the preservation of insulation between adjacent turns of wire, such as winding the wire with asbestos under the cotton. Care must be exercised in using this wire, as some of the forms will not hold the proper number of turns with this increased size, due to the asbestos covering, and if the proper number of turns are put on the form the field spools will not fit in the motor.

Another method used is to slush these coils as they are being wound, or dipping them, after they are wound, in a solution made up of chalk, magnesium-oxide and water to the consistency of whitewash; and this foreign material being introduced into the winding, when baked, hardens and forms a mechanical barrier between the adjacent turns and prevents their short-circuiting.

Other methods are practiced, such as dipping the field coil into varnish or insulating compounds. These different methods all have for their purpose the introduction between the adjacent turns of wire of a non-carbonizable insulator.

The field coils must be well baked after the application of any of these methods in order that any moisture or alcohol may be driven off before the coils are used. It has been the practice to pass current through these coils and heat and bake them in this way; but when water or alcohol is present, internal electrolysis is set up, which forms internally a conducting copper salt, and this destroys the insulating properties of the mediums employed. Another point may be mentioned here in regard to baking where armatures and fields show low to ground after being baked—the baking oven is completely enclosed, and any moisture

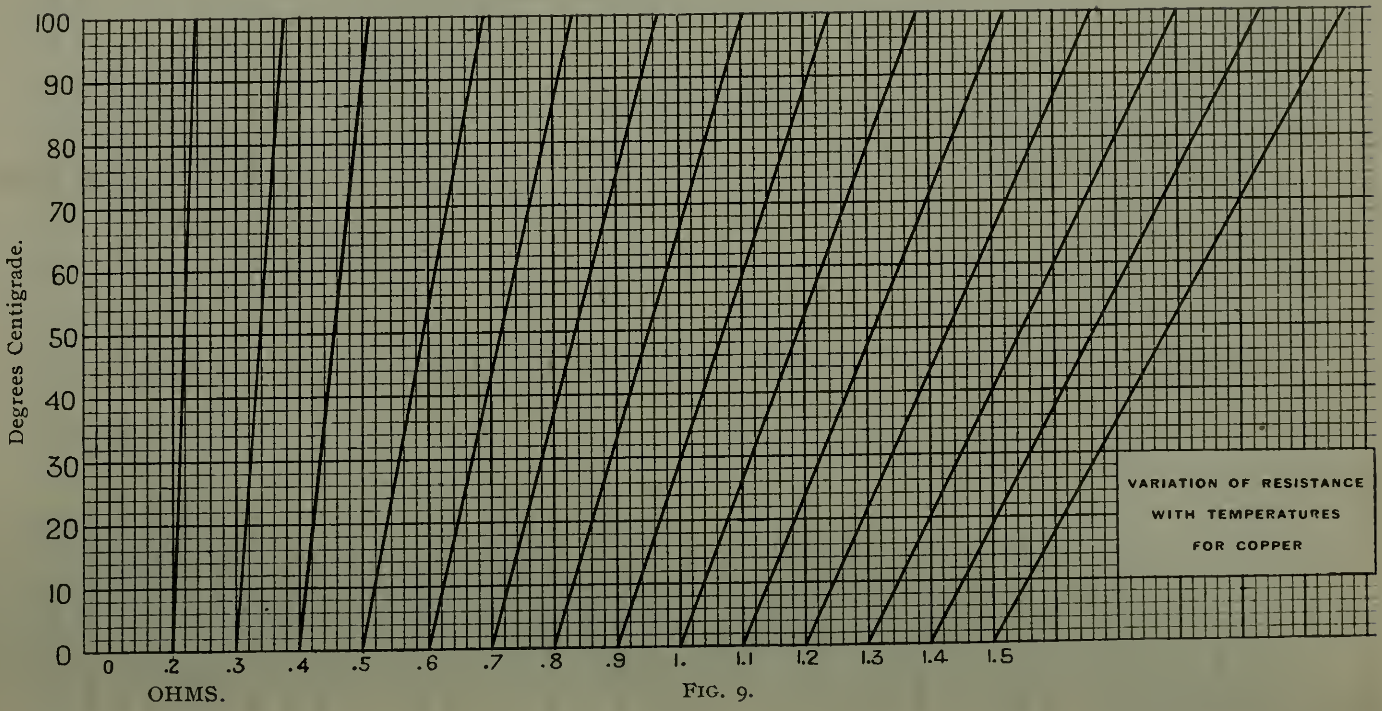

VARIATION OF RESISTANCE
WITH TEMPERATURES
FOR COPPER
Degrees Centigrade.
100
90
80
70
60
50
40
30
20
10
0
OHMS.
0
.2
.3
.4
.5
.6
.7
.8
.9
1.
1.1
1.2
1.3
1.4
1.5

FIG. 9.

excluded from the coil is held in the air. A baking device having no ventilator is really a steam box, and not a baking oven, and high insulation cannot be obtained unless ventilation is provided to the oven.

The best way to measure the temperature of a motor is to measure its resistance when hot, and for each degree Centigrade rise in temperature of the field the resistance will increase 0·38 of 1 per cent. *Fig. 9* gives the increase of resistance for each ·1 of an ohm to 1·5 ohms, and up to 100° Centigrade. The drops in volts across one field when the equipment is running is the best method of testing whether the two motors are taking their loads equally, when they are connected to a series parallel controller. When the motors are in series, they are both taking the same current, and the drop across the field should be reduced one-half when the motors are thrown to multiple, and the same current passing in both cases. If the voltage drop is not cut in half under this condition the motors must be out of equalization, 8 per cent. being the maximum difference in equalization allowed to pass. With the differential method each coil takes the drop off of one field of each motor, and the hand stands at zero in case of equalization. If the hand departs from zero as the speed of the equipment increases, the lack of equalization is due to difference in air gaps of the two motors. If there is a constant deflection for all speeds, the non-equalization is due to the unequal resistance of the two motors in multiple.

In the tests on the armature and its commutator, which is the most delicate part of the equipment, and first succumbs to ill usage or lack of proper inspection of the equipment, the different diseases met with in this part of the motor, are grounds, short-circuits, open coils, broken leads, and broken-down insulation in the commutator, and especially short-circuiting through the commutator ring. Their detection is rendered easy by a bar-to-bar test on the armature. *Fig. 10* shows the method of applying this test to the armature, a brush-holder yoke is clamped to the shaft of the armature, and insulated brushes bear on the bars of the commutator; by moving these brushes around the commutator, the indication of the instrument will be constant in all positions of the brushes; but if an armature is misconnected, there will be a change in values when the brush rests on that commutator bar to which the misplaced lead is connected. Two bars which are short-circuited together when they lie between the four testing brushes will give readings that will be lower than normal. A ground in an armature can be located when one of the measuring terminals is connected to the shaft. The grounded coil connects to that commutator bar which gives the lowest reading on the measuring instrument, when the measuring contacts are revolved around the commutator. Where the insulation is to be measured, the same connections are kept on the armature as for ground, and the test plugs are removed, and the dial turned to insulation test, and plugs inserted in the exposed receptacles; the insulation is read directly in megohms on the insulation scale of the instrument. *Fig. 11* shows method of connecting to the field.

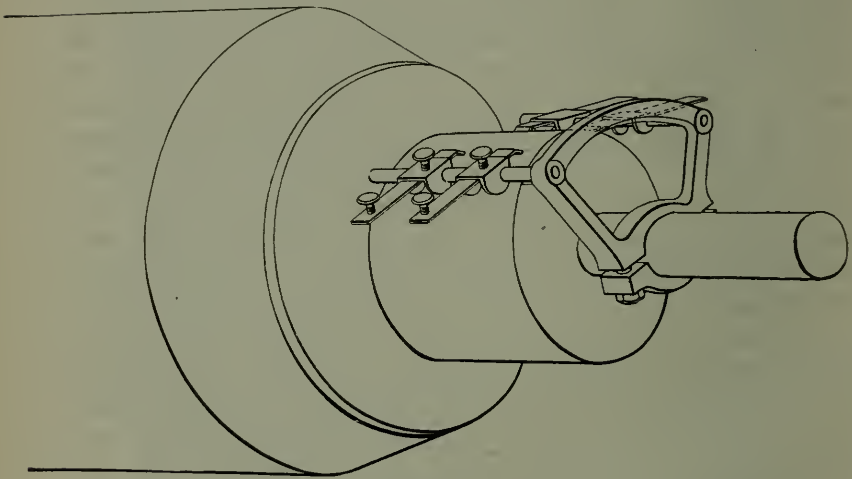


FIG. 10.

The controller has troubles of its own, such as poor contacts of the fingers, short between fingers, grounds, burnt-out segments and misconnections; also the insulating partitions between fingers become carbonized and cause an arc which destroys the contact fingers. Many imperfections in the controlled circuits leave their imprint on the controller. Several of the most prevalent indications will be mentioned, such as the burning of the second resistance contact and the first resistance contact being bright will indicate an open connection in the first resistance step. A bad flash at either loop contact, where loop is cut around the field, indicates an open or poor field connection. In this way many things can be observed in connection with the equipment, and it requires that a successful inspector be keenly alive to all the little external evidences of the internal troubles.

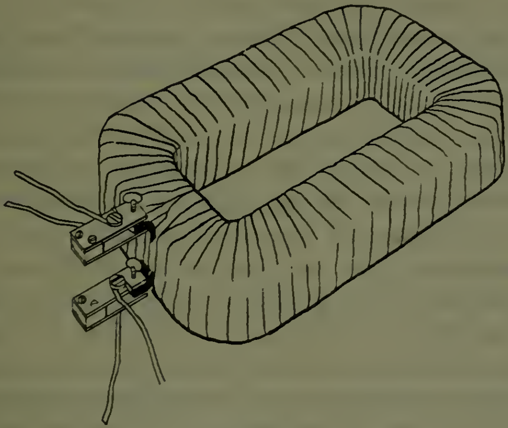


FIG. 11.

And to aid him, I have produced diagrams of connections divorcing the essential apparatus of the equipment from the intricate wiring system so that the conditions of cause and effect can be quickly arrived at.

The controller diagrams that we have studied of type *K* in *Figs. 1* and *2*, show one of five different types, placing them historically. First was the rheostat control, which consists of a resistance in series with one or two motors, as the equipment requires, the function of the controller being to close the circuit and vary the resistance in series with the motors, and in this way controlling the current delivered. The next step in the art of equipment regulation was to first place both motors in series, and also in series with the resistance; after this resistance is cut out the motors are automatically placed in multiple. At this point there is a divergence in connection; one type, such as the *K* controller, places part of this resistance in series with both motors in multiple. The type known as *G* controller in passing to the multiple position places one motor directly across the line potential, and the full resistance in series with the other motor, which is cut out in the succeeding notches of the controller, until both motors are directly across the line. Type known as *No. 14* controller has a separate resistance step in series with each motor; when the motor is in series, these resistances are cut out alternately, both in the series and multiple positions of the controller. Type *C* controller comprehends somewhat the same general arrangement, the relation of the parts only differing in reference to the controller contacts. Each of these controllers has its peculiarities, but to go into them in detail would require too lengthy a discussion.

The wire for car wiring has not been selected large enough in those circuits which lead directly from the motor to the controller, due to the circuitous route that the current takes in a two-motor equipment with a 20-foot car body, the length of this circuit is 217 feet, which of No. 6 wire gave under the condition of equipment tested 12 volts drop in this circuit only; and this drop occurs under the conditions when the motor requires the maximum potential delivery at its terminals; and a few additional dollars spent in the internal wiring of a car would accomplish the same results as hundreds of dollars spent on the line.

The application of electrical inspection of equipments brings out some very queer conditions caused by the car wiremen not fully comprehending the wiring diagrams furnished. In one case I found a number of equipments with both loop boxes connected in series around the field of one motor. Another case I found all the rheostat boxes connected in backwards; that is, the low resistance step connected to the first step, and the high resistance step cut out just before the motors were put across the line. Another case in No. 14 controller, I found where one resistance had always been short-circuited by a misconnection, and the equipments had been working under this condition for several years.

Briefly summing up my experience of the testing of over 1,000 equipments, including nearly all the types extant, I find that the principal weak points are:

(1) That the two way connectors are responsible for a great deal more than their share of trouble, and that every break in the continuity of the conductor system reduces the reliability of the equipment for continuous operation.

(2) That a motor is not any better than its field.

(3) That careless brush inspection is responsible for more burnt-out armatures than those caused by poor motormen.

(4) That the maintenance of an equipment is much more economical and satisfactory than trusting to Providence and awaiting the time until it breaks down; in other words, it is far better for a street railway manager to operate a sanitarium for his equipments rather than a hospital.

The vitality of an equipment rests entirely upon the excellency of its insulation; and the trend of recent improvements in the equipment is to abandon those insulators, which in time either oxidize or carbonize and become conductors.

One final pointer I would like to mention in regard to high-potential alternating insulation tests for railway apparatus, which is generally considered a satisfactory method because it shows so many faults not indicated by other tests, but the application of this high-potential method, with depleted insulation, usually develops the fault which it detects and curtails the natural life of armatures and fields.

Mining and Metallurgical Section.

Special Meeting, March 23, 1898.

BUILDING-STONES—ELEMENTS OF STRENGTH IN THEIR CONSTITUTION AND STRUCTURE.*

By Alexis A. Julien,
Columbia University, New York.

(*Continued from p. 286.*)

III. TENSION OR STRAIN.

We must again recognize, I think, as an essential element of strength, a certain balance of tension or strain among the mineral components of stone. Any disturbance of this by increase, by loss, by expansion or by contraction, by any change, tends to injure the tenacity, coherence and permanence of the aggregate.

Above all other bodies in nature, a mass of rock seems to our eyes to be the most passive and inert; "as dead as a stone," is the common saying. Even though we have learned of the mighty activities by which a rock has been generated and modified—of water, of wind, of chemical action, of fierce volcanic heat—all the violence of these processes is popularly supposed to be long since extinct, all the energy long since dissipated. Yet there is abundant evidence to the contrary; that a vast amount of this force still remains latent, but all ready, after ages of waiting, to issue in active form when released by certain conditions. Rather should we see, then, in every lump of stone a storehouse of enormous energy, any portion of which, if suddenly evolved, may even become explosive. In the crust of the earth beneath our feet, we find ourselves upon a vast unannealed ball, within which not only every molecule lies in active vibration, but fragments of the mass are continually leaping into violent motion. The phases of these stresses near the surface have been produced by crystallization, by subterranean movements and by present physical conditions.

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* Abstract published in *Stone*, 1898, and elsewhere. Reference has been made in the notes to the more important statements which have appeared in the literature of the subject, during the year since the reading of this paper, concerning points discussed herein.

(1) *Tension or Strain by Crystallization.*—A glance at the magnified structure of ordinary building-stone, such as that of a granite (*Fig. 15*),* unveils to us a struggle among its crystal components—quartz, orthoclase, albite, hornblende—all thrusting and straining together for growth within the original plastic mass or magma, each from its own center of pressure, until the process of consolidation and rigidity (usually accompanied by contraction) came to an end. The universal failure of completion here, in this mutual conflict, and therefore of satisfaction of energy, is shown by the total absence of individuals which have perfected their crystal-faces. Not a prism of quartz terminating in its shapely pyramids, nor rhomb of feldspar, nor brilliant hexagon of mica delights the eye. All is imperfection and disorder. The combatants lie before you, interlocked and jammed together, with rough or irregular outlines which bear little or no resemblance to the crystal forms of lovely symmetry which would have developed in isolation—those which actually lurk in sheltered "vugs" or have sprung into form within slowly cooled lavas. At the bounding-planes between these individuals, we find evidences not only of contact and pseudo-welding, but often, if not generally, of mutual pressure or stress and consequent strain. Many facts testify that, in the act of consolidation and crystallization, change of volume occurs. In the metals and artificial alloys, we are familiar in the arts with the contraction, which, at that moment, occurs in lead, and with the expansion, in bismuth and in type metal; also, in the well known constituent of all stones, water, with that rapid and violent expansion, near and at the point of freezing, which rends asunder the most powerful rock.

The student of petrography also finds, under the microscope, ample evidence of the survival of these centers of still active stress. Thus, in a crystal of garnet, found surrounded and locked fast in a plate of mica (*Fig. 16*), the latter dense mineral is seamed by cracks radiating from the enclosed intruder. Sometimes the delicate test of polarized light reveals, too, that the very molecules of the strained garnet, entities minute far beyond microscopical detection, have, by some mystic change under the stress, so reversed their very form and nature as to throw back waves of light in a strange new way, causing the garnet to glow within, where, under ordinary conditions, only darkness would prevail.

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* For illustrations, see the *Journal* for April, 1899.

So again in those fragmental stones which possess a crystalline cement, it is interesting to note an extraordinary separation of grains, as if they had been wedged apart (the interstices being wider than usual in the original sediment) by a strong force, during the crystallization of the interstitial cement—it may be, of calcite in an oolitic limestone (*Fig. 9*), or of quartz in a quartzitic sandstone (*Fig. 10*), and still more in those sandstones of frequent occurrence in which much more quartz has been deposited around each sand-grain in their interstitial enlargement with crystal boundaries.*

As to the exact facts with each mineral, in reference to change of volume during crystallization, whether of contraction or expansion and to what degree, we have as yet little information from mineralogy or physics. But on these as yet unestablished data rest some important characteristics of stone. Such changes of volume, under confinement, might lead to a variety of conditions. With contraction to any extent, the resultant tendency would be toward loose granulation and imperfect coherence; with expansion to a limited degree, increased compactness and strength, or, to an excessive degree, undue strain, brittleness and fragility. In a homogeneous crystalline rock, such as quartzite, marble, dolomite or semicrystalline limestone (*Fig. 12*), if a slight expansion occurred during crystallization, or a decided contraction, either might tend to great compressive strength.

In a crystalline rock of heterogeneous constitution, such as granite, a known succession occurred in the development of its different minerals—usually, first, mica, then feldspars, finally, quartz (*Figs. 2* and *15*). Should the last constituent to crystallize possess the property of expansion, even to a minute degree, its grains would serve as wedges to jam and lock together all its neighbors. Should there come afterward to such wedges some sufficiently heavy pressure, some sudden tensile or compressive strain, some loosening by chemical solution and corrosion, some persistent touch of the finger of Frost upon this key, little wonder should the whole structure of the stone rapidly begin to fall apart. With certain kinds of stone, however, certainly formed by crystallization out of an igneous magma, such as many granites, all traps, etc., there is reason to believe that the remarkable compressive strength has been produced by the opposite process—contraction at the time of crystalline solidification. Professor Niess, indeed, in 1889, after careful weighing of all the evidence, was obliged to conclude that rocks expand on solidifying. But, more recently, C. Barus, as the result of careful trial of one igneous rock (the trap occasionally used for building in the vicinity of New York, Philadelphia and Baltimore), decides that "The present experiments show beyond question, I think, that at least for diabase this is not true. I find that this rock not only contracts between 3·5 to 4 per cent. on solidifying, but that such solidification is sharp and only apparently continuous."* Hoskins also concludes, "Certain known bodies (such as water) expand in solidifying; the solidification of such bodies is retarded by pressure. It is probable that the reverse holds true with the majority of bodies, including rock materials."† These considerations, though partly hypothetical, may suggest important practical results to be expected from physical experiments in this direction on other rocks and on the minerals common in building-stones.

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* R. D. Irving and C. R. Van Hise, Bull. U. S. Geol. Survey, No. 8 (1884).

(2) *Strains Produced by Subterranean Stresses.*—No facts are better established within the observation of the field geologist than those connected with contractile movements, dur-

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* Bull. U. S. Geol. Survey, No. 103 (1893), 25.

† *Loc. cit.*, 847.

ing consolidation of rock-strata, and with their later displacements, in consequence of intense lateral thrusts in the earth's crust. The shoving and curvature of beds, accompanied by stretching on the convex side and by compression on the concave, but in each culminating in innumerable joints, fractures, faults, the sliding and mutual grinding of these fracture-planes, and, on a large scale, the very crushing up of layers into "friction-breccia," "brecciation-conglomerates" and sand, prove that, as J. D. Dana expressed it, "The rocks have been everywhere left in a state of strain, in consequence of the upliftings and foldings to which they have been subjected." From theoretical grounds, Hoskins also concluded: "The occurrence of actual tensile stress in rocks near the surface of the earth is by no means improbable. A bending of strata would tend to cause tension near the convex surface of the fold."* But of this fact many evidences are distinct to the eye, even in hand specimens; cracks radiating apparently from points of concentrated pressure; iridescent rifts, indicating slightly opened cleavage-planes, occupied by air-films; broken crystals, often long prisms, with faulted fragments more or less displaced; scales, plates and huge masses of mica, bent, crumpled, torn and distorted in waves and zigzag folds; great quartz and feldspar-crystals, nodules and pebbles, squeezed down into eye-shaped or lenticular flakes, whose agonizing stare, from cross-sections of porphyry or gneiss with the "augen-structure," testifies to the heavy load under which they have been pressed; quartz-pebbles in the conglomerates actually forced and moulded into each other, with the strange plasticity developed under intense pressures, even in materials the most unyielding; or both feldspar and quartz rolled out, as if mashed and kneaded from soft paste into thin plates and scales.

Investigation has shown,† in the case of strained metals, that the energy applied in the straining has been in large part stored up in permanent tensile stress or "potentialized,"

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* *Loc. cit.*, 874

† C. Barus, "The Mechanism of Solid Viscosity," Bull. U. S. Geol. Survey, No. 94 (1892), 107.

e. g., to the amount of 50 per cent. in "glass hard" steel, strained to the point of rupture: 40 per cent. in brass; 25 per cent. in copper. On this point Van Hise states: "The experiments of Barus and the condition of the Rupert drops show that in strained minerals energy is probably potentialized,"* but elsewhere concludes: "While to some slight degree rocks are elastic when subjected to forces continuing for a short time, it may be doubted whether this property is of importance in considering the slowly acting and long continued forces of rock folding, except perhaps in the slight flexures of great extent. Single rock beds, when much deformed, are rather to be compared to a wrought iron bar, which when bent takes a permanent set. In this case there is an actual flowage of material or rearrangement of the particles to the new conditions."† But it is in the sedimentary strata of gentle flexure, and those too near the surface, *i. e.*, relieved by erosion from their original superincumbent load, that the quarryman resorts for the most easily worked and satisfactory materials for construction, and in these he constantly meets with evidences of unsatisfied stress. He finds them too in the still more compressed granites and crumpled gneisses and limestones, materials containing a far less proportion of yielding voids and probably possessing a higher modulus of elasticity than the arenaceous sediments. These are the very stones in which the petrographer finds, by means of optical tests under his microscope, the constituent crushed granules displaying "strain-shadows," in large part, or even universally, the significant optical tokens of active stress yet remaining.

As to the survival, therefore, in still active form, of part of the enormous force of compression which has been exerted, the miner and engineer, as well as the quarryman, have full proof in symptoms of strain still remaining in the strata among which they are working. A condensed review of observations of this kind (not easily accessible to the builder) may be pertinent, including some not yet recorded, in the hope of inviting further attention to such phenomena in other quarries, with more definite determination of the amount of expansion, the direction and intensity of the expansion or thrust, and the actual changes thereby produced in the microscopic structure and physical characteristics of the expanded stone.

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* "Metamorphism of Rocks and Rock Flowage," Bull. Geol. Soc. Am., IX (1898), 300.

† "Principles," etc., 596–7.

In mineral veins, frequent examples of violent strain have been observed, at least as far back as 1734. In the lead mines of Derbyshire,* the vein stuff, consisting generally of galenite, calcite, barite and fluorite, is divided into more or less vertical sheets or slabs by planes of *slickensides* or *cracking-whole*, which are beautifully polished, so much so in places as to possess the reflective power of a looking-glass, and usually ribbed or slightly fluted horizontally. Such sheets, when bared in the mining operations, fly to fragments with explosive violence, on being struck or even scratched by a miner's pick. "If a sharp-pointed pick is drawn down the vein with a small degree of force, the minerals begin to crackle, as sulphur excited to become electrical by rubbing; after this, in the space of two or three minutes, the solid mass of the minerals explodes with much violence, and the fragments fly out as if blasted with gunpowder. These effects have frequently happened, by which many workmen have been wounded. * * * In the year 1738 a prodigious explosion happened in the mine called Haycliff. The quantity of 200 barrels of the above minerals were blown out at one blast; each barrel, I presume, contained no less than three or four hundredweight." Mr. J. A. Phillips also observed that the explosions occurred after a portion of the vein had been undercut, and suggested that the removal of one side of a vein would leave the remaining side in a condition of strain, resembling that of a strung bow, with a tendency to bulge outwards into the workings. The undercutting would free, so to speak, one end of the bow. Mr. W. Bowman had noticed similar explosions of limestone in the Ecton mine and in the Clayton adit-level, where the beds are sharply contorted and crushed. Mr. Strahan concludes that in the veins "the spars are in a state of molec-

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*A. Strahan, "On explosive slickensides," *Geol. Mag.* (1887), 400.

ular strain, resembling that of the Rupert's Drop, or of toughened glass, and that this condition of strain is the result of the earth's movements which produced the slickensides."

In coal mines of Great Britain, also, particularly where the strata are much faulted by dislocations, and at great depth, and in drifts in advance of the general workings of the mine, and in the lower part of the coal-seam, loud reports or "bumps" are of every-day occurrence, often accompanied by the bursting off from the sides of the excavations of large blocks or masses of coal, sometimes even displacing hundreds of tons. The noise made by such "explosions" or reports may be likened to artillery, and often causes men to run out of the place with alarm. During the operation of "holing" (under-cutting the coal-seam preparatory to breaking it down), the coal will keep on bursting itself off in little fragments from the face of the excavation with loud explosive reports, often putting the men's candles out. When the coal does this, it is said to have plenty of "life" in it, or "it keeps talking to you." These explosions, as well as the strange sounds heard when all work is suspended, rattlings, scratchings, knockings, etc., noises called "nackings" by the men, and also the subterranean rumblings heard on the surface, are attributed, not to escape of gas, but to "the upsetting, by the excavation, of the equilibrium of the strains or pressures holding everything fast and firmly together—the removal of the support thereby causing the rocks to get relief and to fly off or apparently to explode."*

In the gneiss quarry at Monson,† Mass., the strike is N. 10° E., and the dip W. 10° N., at an angle of 80°; but the only divisional planes consist of a set of parallel joints, separating the rock into beds which are nearly horizontal or dip about 10° to the west, nearly parallel to the general surface of the hill, and vary in thickness from a few inches to several feet. During the quarrying by splitting off stone, by wedges, parallel with the strike, whenever a stone of considerable length is thus separated from any entirely undisturbed portion of a bed, it is found that the stone expands lengthwise, as indicated by the movement of the drill-holes on the side near its freed end. These movements may be either uphill or down, but they are always in northerly or southerly directions, with the strike of the rock; no traces of expansion in easterly or westerly directions have been ever seen; they have occurred during all conditions of the weather, warm and cold, wet and dry. In one mass of rock, 354 feet long, 11 feet wide and 3 feet thick, the amount of expansion after dislodgment was 1½ inches up the slope of the hill. When the fracture by wedging is suddenly and thoroughly made, the expansion takes place immediately, and sometimes the expansive force itself completes the desired work, the stone suddenly springing into the elongated state. Spontaneous fractures also occur, of which one was fully 4 inches wide. On removal of overlying beds, spontaneous upward bendings and swellings of the lower beds also occur, most frequently in the thinner sheets, up to 4 feet in thickness, with formation of miniature anticlinals. The amount of elevation varies from ¼ inch to 3 or 4 inches, even in a single afternoon. The span of the arch thus formed is sometimes 50 feet, while some are only 3 feet broad; the crests always trend in easterly and westerly directions, are sometimes ruptured, and are evidently caused by expansive thrust in northerly and southerly directions, since the edge of the sheet at each base of the anticlinal arch remains so closely attached to the underlying bed that no lateral slipping of this edge upon the rock could possibly have taken place. In one arch, which measured nearly 60 feet from base to base, of a bed 10 to 16 inches in thickness, the stone was found to have stretched at that time more than $\frac{1}{1000}$ of its original length.*

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* W. S. Gresley, R.E., "Explosive Slickensides," *Geol. Mag.* (1887), 522.

† W. H. Niles, "Some Interesting Phenomena Observed in Quarrying," Proc. Boston Soc. Nat. Hist., XIV (1870-71), 80-86; and, "On Some Expansions, Movements and Fractures of Rocks, Observed at Monson, Mass.," Proc. Am. Ass. Adv. Sci., XXII (1873), B, 156-163.

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* W. H. Niles, "The Geological Agency of Lateral Pressure Exhibited by Certain Movements of Rocks," Proc. Boston Soc. Nat. Hist., XVIII (1875-76), 283.

Another result of this rock expansion is the formation of numerous cracks and fissures, by which in one case 10,000 tons of rock were moved. These are commonly formed slowly, but sometimes suddenly, attended by the shattering and crushing of solid rock, loud reports, cracking and explosions, and the hurling of stones of considerable size for a short distance and to a height of several feet.

In a quarry of gneiss at Waterford,* Conn., slight movements of the rock have been observed under the following conditions: In using the steam-drill for cutting out blocks of stone from the rock in place, if the holes are made very near each other, the small portions of stone thus left between them are often crushed, and the drill so pinched that it cannot be worked. The pressure is limited in its action to a northeasterly and southwesterly direction. The quarry is located a little east of south from Monson, at a distance of nearly 60 miles in a direct course. The stone quarried there, commercially known as Millstone Point Granite, is a gneiss, which, although differing somewhat in external appearance from the Monson stone, is of similar constitution and texture, and occurs under similar geological conditions.

In the town of Groton,* Conn., evidences of pressure were observed upon some thin sheets at the bottom of one of the small quarries.

The phenomena above briefly described were found to be independent of conditions of temperature or moisture, being observed at all seasons of the year and during all kinds of weather. The direction and intensity of the movements showed that they could not have been produced by vertical pressure, such as the weight of adjacent overlying rock and loose materials. It has been pointed out by Mr. Niles that their northerly and southerly direction is identical with that of the pressure established at the close of the Tertiary Age which caused the changes of level in the northern part of the continent during the Quaternary Age, as well as with that of recent changes of level of the Atlantic coast.

At New York City, some years ago, during excavation of a tunnel under the East River, many blocks of gneiss were observed from time to time to start from their places with almost explosive violence.* Similar observations have been often made in the granite quarries at Westerley, R. I., in Southwestern Virginia and elsewhere. In those at Barre, Vt., I am informed that holes and grooves, cut during drilling and channeling, have been found gradually closing up in a mysterious way, though the observer was not certain whether this was due to expansion of the surrounding work or to its gradual sliding down a gently inclined bedding-plane.

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*W. H. Niles, "The Geological Agency," etc., 279.

In sedimentary rocks, also, evidences of tensile or compressive strain have been frequently observed. For example, at Wilmot's flagstone quarry, on Basket Creek, N. Y., the quarrymen removed the top, one day, from a ledge of rock extending back about 11 feet, and began raising the lifts of flagstone (a rock similar to that shown in *Fig. 6*): "The ledge is only some 7 or 8 feet high and over 40 long. After a few top-layers of stone had been taken off, it was noticed that the lifts under them began to rise in spots, and in a short time would rise up clear across the ledge, much in the same way as flooring will occasionally become so swollen as to bulge up at some point in the shape of the roof of a house. This was at first ascribed to the heat, as it was in the afternoon, and the sun shone in very hot upon the ledge; but as fast as one lift was taken off, the one below would begin to rise in the middle, as though, being wedged or sprung in at the ends, they rose in the middle as soon as the weight was off. The lower in the ledge the men got the stronger seemed to be the impelling force; and on Friday the men found, on going to work in the morning while it was cool, that during the night an immense course of stone had risen in the center of the ledge, extending across the 11 feet to a height of 7 inches, and sloping like the roof of a house each way to the ends of the ledge."

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* "This is a gray gneiss much like that at the north end of Seventh Avenue and near One-Hundred-and-Fiftieth Street. At one place, 150 to 250 feet east of the west shore of the (Blackwell's) island, it proved to be under great strain, so that from time to time, even six months after the tunnel was opened, it cracked with reports like a pistol-shot, and at intervals masses fell from the roof."—J. F. Kemp, "The Geological Section of the East River at Seventieth Street, New York," Trans. N. Y. Acad. Sci., XIV (1895), 275.

In the sandstone quarries at Portland,* Conn., the beds dip about 12° or 15° to the southeast, and had been excavated to a depth of 140 feet below the original level of the soil. At the bottom of this cavity a channel, 1 foot or more in width and some 50 or 80 feet in length, was rapidly sunk by several workmen with their picks, in an east and west direction. The stratum had been found to be about 6 or 7 feet in thickness, and "when the channel had been sunk to within about 9 or 12 inches of the bottom of the stratum, suddenly the remaining stone at the bottom was crushed to fragments with a loud report by an enormous lateral pressure, and the men in alarm leaped from the excavation they had made. By examination it was found that the walls of the groove or canal just made had approached each other about $\frac{3}{4}$ of an inch, the stratum through which they had cut having on one side slidden this distance in its ancient bed." This has repeatedly happened in channels excavated in a new stratum in an east and west direction, at or near the bottom of the quarry, and but in slight degree in channels cut north and south.

In the sandstone quarries at Berea,† O., the beds are of different thicknesses and are nearly horizontal in position. An important part of the work of quarrying is the cutting of trenches in the beds, which are just wide enough for the men to work in. Where the quarries are well opened, these are usually cut perpendicularly into the working face, *i. e.*, east and west, where the faces commonly run north and south. It has been found that on approaching the lower surface of a bed with a long cutting, the stone remaining at the bottom of the channel has been broken or crushed, and portions of the stone desired for use have been so fractured as to be rendered worthless. For this reason the trenches are cut through in short horizontal sections to the bottom of the bed. Even with this care, sudden lateral slippings of the stone have frequently taken place, especially when the channels were nearly completed. These have usually been attended by cracking and explosive sounds, and sometimes the movements have been of such violence as to throw pieces of stone from the surface, or to crush portions of the rock into small fragments. In these instances it has been found that the portion of the bed which has moved has also permanently expanded, so as to narrow the channel perceptibly. There have been instances in which the expanding rock has not only closed the channel, but has also pressed against the stone which was upon the opposite side of the trench with such force that it has been broken. On one occasion the edge of the expanded portion of a bed was observed thrust over the other edge, so as to bring one portion vertically above another part of the same bed, which was originally some 15 inches or more from it horizontally. If, now, another channel be cut in such a bed, parallel with the first, but at some distance back into the face, there will be either no apparent movement of the rock or it will be much less than that which followed the cutting of the first channel, showing that the force has been partly or wholly expended. The movements are greatest and most energetic in a northerly and southerly direction, but comparatively small where north and south channels have been cut.

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*J. Johnston, "Notice of Some Spontaneous Movements Occasionally Observed in the Sandstone Strata in one of the Quarries at Portland, Conn.," Proc. Am. Ass. Adv. Sci., VIII (1853–54), 283–6.

† W. H. Niles, "The Geological Agency," etc., 273.

In the quarries of "Athens marble" at Lemont,* Ill., the pot-holes occurring in the water-worn surfaces of the upper layers of the limestone, when of sufficient depth to penetrate one layer and enter another, are occasionally found to be dislocated—that is, one layer has slipped upon the other, so that the upper and lower portions of the pot-hole are in some cases entirely separated from each other. The dip is hardly perceptible, not more than 1° or 2° to the southeast. A similar dislocation of drill-holes was observed and was a clear evidence of lateral sliding, for the parts of the drill-holes remaining upon the edge of an upper layer were not vertically above the lower parts of the same holes shown upon the edge of the under bed. In one quarry, also, there was an elevation of a part of the bed forming the floor. It was an anticlinal axis of more than 800 feet in length, and its trend was nearly east and west. In its most conspicuous part the elevation was from 6 to 8 inches, and the arch measured from 16 to 18 feet from base to base over the crest. It was formed along the line of a vertical joint, which extended beyond the limits of the quarry. The contiguous edges of the bed were bent upward, making an elevation which was a little more upon the north side of the joint than upon the south, and a slight fault was in this way produced.

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* W. H. Niles, "The Geological Agency," etc., 277.

The testimony of earthquakes is beyond question, to the sudden yielding and slipping of strata, in response to accumulating strain at certain points. Such phenomena are common not only in volcanic districts, but in regions of crystalline rocks where other evidences of compression have been observed. In the lower Connecticut Valley, such disturbances have been accompanied by both jarring and sounds, the mysterious "Moodus noises," early known to the Indians, and heard by the first colonists from 1709 to 1729; they again occurred in 1852 and 1885. Still more recently, in 1897, "there was a sound like a clap of thunder, followed for some two hours by a roar like the echoes of a distant cataract. A day later, there was a crashing sound like heavy muffled thunder and a roar not unlike the wind in a tempest. The ground was shaken, causing houses to tremble and crockery to rattle 'as though in an earthquake.'"

It might reasonably be presumed that rock-strains, of sufficient intensity to have produced such remarkable phenomena to the eye and ear, must have also generated abundant internal evidences of stress, on a minute scale, throughout the material of stone. Under the microscope, these "strain-phenomena" form the subject of constant observation by the petrographer; the same cracking, stretching and flattening of crystals and nodules; the bending, crumpling, twisting and splitting of mica-plates; the "strain-shadows" in quartz-grains, and optical anomalies, caused by still active pressure in garnet, leucite, haüyne, etc.; the parallel sheets or bands of fluid-cavities or fissure-inclusions,* in quartz (*Fig. 15*), crossing through adjoining tongues of feldspar, fractured blades of fibrolite, etc., and marking the directions of shearing-strain; the secondary lamellar twinning and gliding-planes in plagioclase-feldspar and calcite (indicated by the parallel stripes, *Fig. 17*); the schiller structure in hypersthene; and the so-called "cataclastic" structures, represented by the cracking and crushing of grains into friction-breccia, into sand-grains surrounded by fine particles (mortar-structure), and even to a finely granular uniform mass ("mylonite"), in which all original forms have been ground down and obliterated.

The coincidence of solution-planes in a mineral (*i. e.*, those of most ready yielding to chemical action) with certain crystallographic faces, twinning-seams and the gliding-planes developed by shearing-strains, suggests the connection of such stresses with directions of easiest attack by weathering agencies within the material of building-stones. For these peculiarities of structure characterize minerals which predominate in the constitution of stones used for building, viz., the feldspars, calcite, dolomite, etc.; and they call for more thorough investigation in application to the needs of the builder.

Sorby† has long ago shown, in connection with metamorphism of rocks, the effect of pressure in increasing the solubility and rapidity of removal of certain minerals, especially calcite, and the subject has been later discussed by Van Hise. It may therefore be possible that the detection of abundant "strain-shadows" or other evidences of the presence of active stress among the grains of a rock may be safely taken as evidence of its ready tendency to attack and disintegration by atmospheric waters and of its unfitness as a durable building-stone.

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* A. A. Julien, "On the Fissure-Inclusions in the Fibrolitic Gneiss of New Rochelle, N. Y.," *Am. Quart. Micr. Jour.* (1879), 1–15.

† H. C. Sorby, *Quart. Jour. Geol. Soc.*, XXXV (1879), 88.

Some measure of the intensity of these stresses, as estimated from the thickness and weight of the superincumbent strata required to produce them in particular instances, has been deduced by certain investigators from the contents of microscopic fluid-cavities. These abound in the quartz-grains of granites and gneisses, often to the amount of 1,000 millions to the cubic inch, equivalent to 1 per cent. of the volume of the quartz. They are shown in the quartz-grains in granites (*Figs. 2* and *15*), and still more plainly in that of Fox Island, Me. They may be partly filled with water, brine, or often liquid carbonic acid with floating bubble of gas. The condensation of the last substance as a liquid, at 32° C., requires a pressure of 38½ atmospheres, or over 600 pounds to the square inch. The intensity of pressure and the temperature prevailing at the time of consolidation of the rock have been the object of observations and experiments by Profs. H. C. Sorby and W. N. Hartley. The floating bubble in a cavity was held to represent the vapor-filled vacuity, left on contraction by cooling of the liquid which originally filled the whole cavity. By determination of the temperature at which the liquid could be compelled artificially to resume its original volume in selected tubular cavities, it was estimated that, in granites of the Scotch Highlands, the rock had been consolidated under pressures of about 69,000 to 76,000 feet of rock at temperatures between 200° and 360° C., a dull red heat.

The amount of strain now remaining in such a granite may be inferred from the fact that its liquid contents often reach as much as $\frac{1}{10}$ or $\frac{2}{10}$ of 1 per cent. of its weight, *i. e.*, 3 or 4 pounds of liquid under intense compression to a ton of the rock.

A natural corollary from these views is that the constructor, in the selection of stone, should give preference, other things being equal, to material from beds whose geological position (*e. g.*, in the "neutral plane" of a flexure) and whose texture imply the absence of serious tension, *e. g.*, dense sandstones from horizontal strata, limestones presenting few crevices and veinlets, and probably granites whose quartz-grains are poorest in liquid inclusions.

In regard to the recrystallized limestones, the marbles, it has been pointed out by Van Hise,* that calcareous sediments, after a dynamic movement has ceased, show a marked tendency to recrystallization in presence of warm solutions and under static conditions; and that the particles recover from a state of strain in the progress of this rearrangement, so that the calcite-grains usually show little or no strain effects. In massive marbles we may therefore have little fear of danger from remnants of active tension.

(3) *Strains Caused by Present Physical Conditions.*—We have still to consider certain physical conditions to which stone is subjected by which abnormal strains are produced, aside from artificial strains developed within masonry during construction.

By changes of temperature caused by vicissitudes of climate, it is evident great variations of tension must be generated in masses of stone, not only between its superficial and deeper-lying portions, but also still more variant between its component mineral-grains. The latter are due to the difference in amount of expansion by heat of the various kinds of minerals,† *e. g.*, the coefficient of cubical expansion for quartz (0·000036) is over twice that of orthoclase feldspar (0·000017); also to the difference in degree of linear expansion within each mineral in the directions of its crystallographic axes, *e. g.*, varying in the axes of a common form of feldspar, adularia, as 659:2914:15687, or as about 1 to 4·4 to 23·8. In other words, the grains of one of the most common constituents of rocks expand over four times as much in one direction as in another, and nearly twenty-four times as much in a third direction!

The efficiency for harm in such enormous variations must depend chiefly, it may be presumed, on sudden increments to tensions already existing and on consequent sudden developments of energy and movement within the stone. Thus occur, in extreme cases, violent expansions of rock on arid plains and in torrid regions, under thermal variations which may reach even 100° F. or more in a single day. For example, in the Trans-Pecos region of Texas, where diurnal variations of temperature amounted to 60° to 75° F., Streeruwitz heard, on the heights of the Quitman Mountains, peculiar crackling noises and occasional loud reports, caused by the scaling off from the solid rock of broad flakes up to 4 inches in thickness, and by the splitting of huge boulders under the heat of the sun.

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* "Principles," etc., 703, 707, 771.

† F. W. Clarke, "The Constants of Nature," Smithson. Misc. Coll., XIV.

Similar changes of stresses and movements also occur among and within the blocks of stone in masonry exposed to the sun and weather, under ordinary daily temperature-variations. An interesting example of these has been recently reported to me in regard to a five-story building in Warren, Pa. Its solid ashlar front, facing westward, is constructed of the purple-brown Hummellstown sandstone, in blocks commonly 2 feet in height, 1½ feet in thickness, and from 3 to 8 feet in length. These are now found to be, in many cases, fractured completely across, the crevices opening 2 or 3 millimeters during the day and closing at night. These fractures and movements, apparently caused by alternations in special absorption of heat and expansion by the dark stone and in its nightly radiation and contraction, indicate a constant increase and release of tension among its grains—their constant swing to and fro under the daily changes of stress—their failure to recover their exact original positions, and a constantly increasing divergence of certain masses of the stone. In experiments of the U. S. Engineers at the Watertown Arsenal, it was found that bars of stone, 20 inches long, after being heated 180° and again cooled to the starting-point, 32° F., still retained a slight expansion, "permanent swelling," which amounted, in several granites, to 0·004 inch; in marbles, 0·009 inch; limestones, 0·007 inch; and sandstones, 0·0047 inch. Observations on masses of stone like those above stated at Warren seem to show that such permanent swelling increases, by frequent repetition of alternations of temperature, to a degree which may seriously injure and even endanger its cohesion.*

When exposed directly to flame, during burning of buildings, the expansion and stress may become so great as to produce violent explosions, especially of granite, where the bursting of fluid-cavities in quartz may be also involved. The fire-tests hitherto recorded, to determine the resistance of varieties of stone to such violent changes of temperature, are confined to a very few series, comprising but a limited number of kinds, and without the uniformity of method desirable for safe comparison of results. Even at ordinary temperature-variations in the atmosphere, expansions and contractions of notable amount occur, sufficient to embarrass or defeat the builder in constructing water-tight joints in coping of walls, flagging over vaults, casemates and tunnels, etc.

Strains result also from processes of chemical action progressing within stone, such as absorption of water, oxygen and carbonic acid, with enormous expansions in volume. The oxidation and decay of iron sulphides, I have elsewhere shown,† depends, to any degree of practical importance to the builder, not only on the intimate molecular intermixture of marcasite, but the very amount of this can be predetermined in crystals of pyrite which appear to be pure. The softening of micas and kaolinic decay of feldspars, however, are the most deleterious agencies of this kind. With accompanying aid of antecedent latent tensions, and those developed by heat of the sun by day, chilling contraction by cold rainfalls and by night radiation, and the final rending strain of enclosed water-films solidified by frost, it is not surprising to find the exterior of a strong stone exfoliating in plates and concentric crusts.

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* This process has been recently well described in detail by G. P. Merrill: "The mass of stone is made up of an admixture of mineral particles without definite order of arrangement, and all practically in actual contact with one another. As the temperatures rise, each mineral expands ever so slightly and crowds against its neighbor; but aside from the unequal expansion of minerals of different species, the process is further complicated by their tendency to expand unequally along their different crystallographic axes. So all through that portion of the stone thus warmed there arises a condition of very unequal tension, which is naturally greater the greater the amount of heat. As temperatures fall, a corresponding contraction takes place; but in material so granular and inelastic as stone, the particles do not again recover exactly their original relative positions. Minute rifts are opened, not merely between the granules, but also along the cleavage-planes of the minerals themselves, so that in time all cohesion is lost and the stone becomes so weak as to fall away to the condition of sand, or, as is more commonly the case, absorbs so large an amount of water that, when freezing ensues, disintegration results."—Rep. Maryland Geol. Survey, Vol. II, 1898, p. 92.

† "Pyrites in Building-Stone," Ann. N. Y. Acad. Sci., IV (1887), 216-223. See, also, paper of A. P. Brown, Proc. Am. Phil. Soc., XXXIII (1894).

It is the multiplication of all these stresses, though often individually minute, the accumulation of these apparent trifles in tension, which seems to account largely for the anomalies constantly observed in the resistance of stones to crushing and other mechanical strain, and for the variations in their endurance of atmospheric attack. With the nature and degree of such latent strains once comprehended, tested and provided for, a builder need no longer be mortified, in handling a stone of known high crushing strength, to find it subject to sudden and apparently capricious fractures—in ashlar, pillars, or sills, it may be—even at low amounts of actual compression, well within the accepted limit of security. At least, such occurrences should be ultimately confined to the shearing-stresses produced under conditions of insufficient support, such as imperfect adaptation of hewn blocks, lack of mortar, or yielding foundations.

[*To be Concluded.*]

CHEMICAL SECTION.

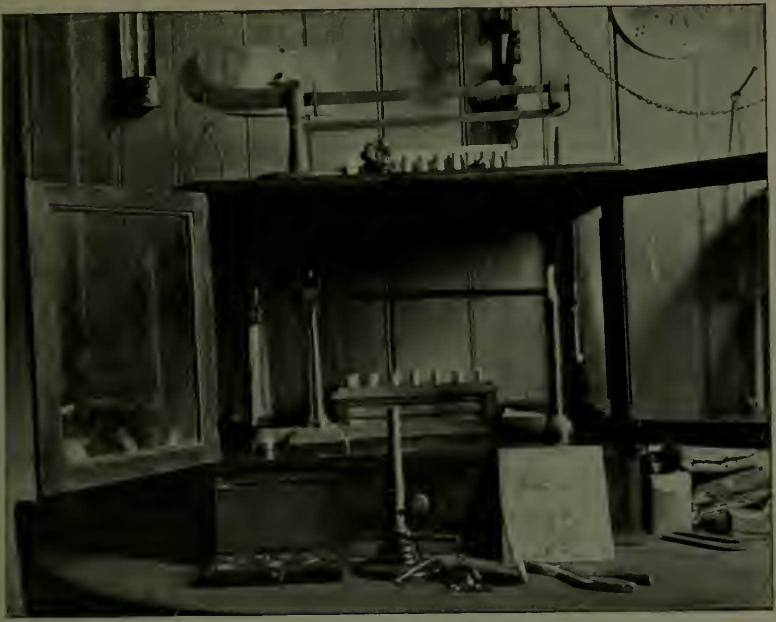
Stated Meeting, February 21, 1899.

QUICK TESTING OF LEAD-TIN AND LEAD-ANTIMONY ALLOYS.

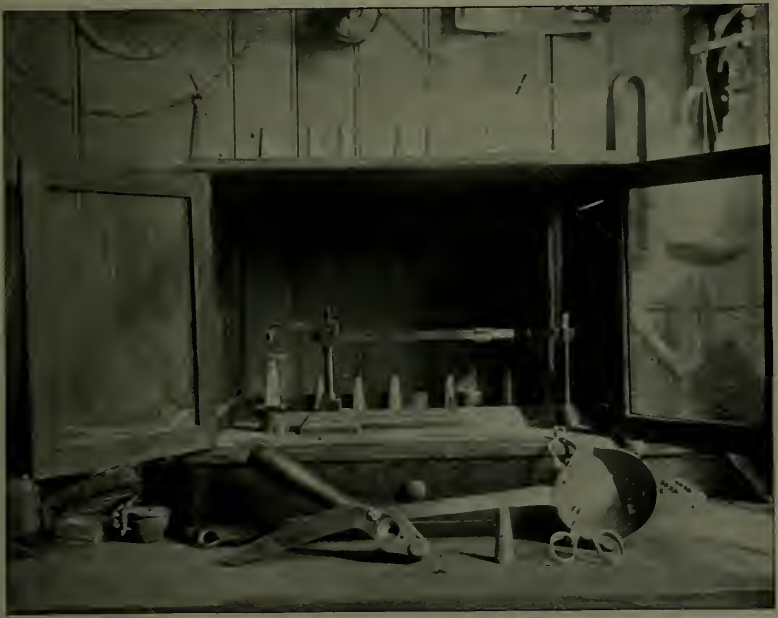
BY JOSEPH RICHARDS,
Member of the Institute.

While great strides have been made in analytical chemistry, yet there is in the direction of quick work a field for the chemist that needs urgent attention, and as far as he has been able to meet this demand the metallurgist is benefited by the progress made and the results attained. I allude to methods of quick determinations, approximately true and sufficiently so for the purpose required.

My own experience for the past thirty years has been confined almost exclusively to the working of the white metals, such as lead, tin, antimony, aluminum and zinc. It is well known that the bulk of the lead ores are contaminated with antimony, and in the refining of lead, the antimony when at a dull red heat is rapidly oxidized and floats on the top of the molten metal as a scum, carrying particles of lead with it. This is removed as fast as formed, and in the course of ten to forty-eight hours all the antimony is eliminated. It is very desirable in this process that the workman should know how he is progressing in his work; and in order to meet this demand I have made a series of tests of the relative weights of standard alloys of antimony and lead, from pure lead up to 24 per cent. of antimony. At this point the lead is saturated, and if more than that quantity of antimony is present it will float on the top of the molten mass; so that a standard alloy of 24 per cent. of antimony is the highest that can be tested by my apparatus. I made castings of these alloys in a mould, took the average weight of 10 of each grade, and the machine was marked to exactly balance at the line or weight given by the average test. This I continued from pure lead up to 24 per cent. anti-



MACHINE FOR TESTING TIN PLATE.



BALANCE FOR TESTING TIN-LEAD ALLOYS.

mony; thus a quick and reliable means is at hand, so that all the workman has to do is to carefully cast his bullet, place it on the balance, and it shows him at once the amount of antimony in the mixture. The following difficulty here arose: while antimony is lighter than lead, if a small amount of antimony is present (less than 2 per cent.), instead of making the bullet lighter, it is heavier than pure lead, and it is not until over 2 per cent. is present that its weight becomes less than that of lead. This difficulty I overcame by discovering that the physical properties of these alloys is such that if a small button is poured on a flat plate and allowed to cool, the surface is not at all like lead, but of a fine white crystalline appearance. So I have supplemented my test machine with a set of buttons of a known composition from 2 per cent. down to zero, changing composition by $\frac{1}{10}$ per cent. in each button. I made the first button 2 per cent., the next $1\frac{9}{10}$ and so on down to pure lead.

Thus the operator can go on with his work until there is a perfectly lustrous surface, free from frost, and at this point the lead will be 998 fine or over. The practical value of these tests is shown by the fact that since I made the first machine for the National Lead Company their order has been duplicated six times.

Another method of quick testing was needed for the alloys of lead and tin. When I commenced this business the only way I could find out the percentage of tin in solder, solder joints, pewter and such like metals, of which we were buying hundreds of tons each year, was by chemical analysis, and I found this took several hours and required great care and much practice to get accurate results. The use of the specific gravity test was suggested to the writer by an old member of the Institute, Mr. G. H. Perkins, but the means employed were crude and unsatisfactory. So I again commenced with pure lead as a standard, taking 99 of lead to 1 of tin, and so on till I got up to pure tin. I made over 2,000 tests, confirmed them by analyses of the metals used, and so made a set of standard weights, from which standards the scale now before you was marked; each mark being the average of about twenty tests, and is correct to the tenth of 1 per cent. I may here remark that the weight of these alloy bullets is, for some physical reason, different from the calculated specific gravities of the alloys, some being heavier and some lighter than the calculated weights. The machine before you has a graded beam, and the moulds are all made to an exact standard and are all interchangeable. If a firm loses or breaks a part of the machine, it can be easily replaced or a new mould procured. So that now, when we melt alloys of tin and lead, we do not even have to depend on accurate weighing of the metals to be melted, but test each pot and can check any error that the workman might have made in his weighing. So accurate is this test that a difference of a quarter of 1 per cent. is easily detected, and my experience in my own laboratory and with samples sent to a number of good chemists, is that I would every time prefer my test for practical purposes to that of the ordinary chemical laboratory.

When we consider that many thousands of tons, roughly estimated at 75,000 of solder alone, are used in the arts every year, one may easily perceive how valuable a factor to the trade such a machine as this becomes, and it has been so recognized, for at this time at least nine-tenths of all the smelting and refining works in the United States are using my machine. Also in the new industry of manufacturing roofing-plates with tin and lead alloy coating, called terne plates, I find that I have supplied three-fourths of the plants with these machines; so that they may test and keep regular the proper percentage of tin and lead in their bath. Many large purchasers of solder find such a testing machine indispensable to protect themselves from lower grade metals than they pay for. This simple, accurate and altogether satisfactory method of testing is therefore now in common use.

In my machine for testing roofing-plates, the beam is so adjusted that if a piece of the sample plate exactly cut to template size and then weighed on the scale, gives the weight of a box of 20 x 28 plates in pounds. For instance, if the plate cut shows a weight of 220 pounds, that is the weight a box of plate would be with the coating on it. This piece of plate is then heated over a Bunsen burner till the coating melts, then wiped clean, heated again and wiped till no more metal is on the surface. When the surface is blue all over, showing that all the coating is removed, weigh it again. If it now weighs 200 pounds, this will be the weight of the black plate per box and the difference between the two weighings is the weight of the coating in pounds.

NOTES AND COMMENTS.

THE SMOKE NUISANCE IN PARIS.

Notwithstanding the general impression that Paris is a notably clean city, the growth of the smoke nuisance has forced the municipal authorities to take measures for its regulation by legislation. Before proceeding to do this, however, they appointed, in 1894, a technical commission to investigate the subject. This body has lately completed its labors and has published a report embodying its results and recommendations, an abstract of which is herewith taken from *Engineering Magazine.*

The commissioners instituted a series of tests with the view of determining what were the best attainable smoke-preventing devices, and offered prizes to the furnaces demonstrating the best results.

The outcome of this procedure was the entering for competition of no less than 110 smoke-preventing appliances, which may be classified as follows:

(1) Mechanical stoking and uniform combustion	16
(2) Supplementary injection of hot or cold air	20
(3) Injection of steam with or without addition of air	5
(4) Mingling of flames and combustion of smoke	7
(5) Gas producers and gas firing	7
(6) Pulverizing the fuel previous to combustion	2
(7) Washing of the discharge gases	16
(8) Miscellaneous systems	37

The following information relates to the manner of making the tests:

"The various devices were successively erected under the same boiler * * * and the same fuel was used in all the tests. The fuel was the Anzin briquette, of the ordinary quality, containing an average of 8·17 per cent. of ash, and 17·84 per cent. of volatile matter. Each device was subjected to two kinds of tests, one with slow firing, and the other with the firing forced to supply the engines fed by the boiler to their full capacity. Each test was made twice, the first time with a stoker selected by the maker of the device, and the second with the stoker employed by the commission, thus eliminating as much as possible the personal equation. * * * The tests included the determination of the quantity of fuel burned per unit of grate area, and the evaporation per unit of area of heating surface and per unit of weight of fuel, as well as the measurement of the relative amount of smoke produced.

"The measurement of the amount of smoke produced by each device was accomplished by an ingenious method, which, while probably hardly entitled to be considered as a method of precision, was still reasonably correct, and doubtless fair to all the devices tested.

"A smoke scale of five degrees of intensity, ranging from complete absence (of smoke) to complete opacity, was decided upon, and the amount produced was recorded upon cylinders revolved by clockwork, by means of a pencil which could be pressed into contact with the paper by hand. The observer, watching the chimney top, pressed the pencil against the paper during any period when smoke was produced, the paper being divided into five portions corresponding to the five grades of smoke."

So much for the method of the tests. The conclusions, which are of general applicability to all cities where the smoke problem is a live question, will be read with interest:

"In the first place, the experiments made before any of the special devices were tried, showed that the ordinary grate is unsuited for smokeless combustion, and that, even with the most careful stoking, the common grate will permit the formation of smoke.

"In the second place, it was clearly demonstrated that smoke prevention and economy do not necessarily go together. The blackest of smoke represents an insignificant amount of fuel, and the tests demonstrated that the devices which produced the least smoke were not the most economical. It should, therefore, always be assumed that the prevention of smoke involves expense, proper allowance being made therefor.

"Smoke may always be prevented by using coke, but as this is in many cases unavailable, the only remedy lies in the use of such devices as will produce a minimum of smoke, the true principle being, not the combustion of smoke, but the absence of its production.

"The commission recommended the prohibition of dense black smoke, as the trials showed that many devices would accomplish this result. It was also recommended that those devices which showed the best results during the tests be placed in manufacturing establishments with the view of establishing their durability and effectiveness in regular service, and, above all, that the existing regulations be thoroughly enforced by patient and competent officials." W.

RENDERING CALCIUM CARBIDE STABLE IN THE AIR.

Calcium carbide, as is well-known, rapidly disintegrates when exposed to the air, through the action of the moisture therein contained; hence, it is necessary to preserve it in hermetically-sealed vessels until it is required for use.

In a recent English patent, the inventor proposes to obviate this difficulty by "saturating the carbide with liquid hydro-carbons, as for instance, petroleum." By this process, the carbide, immediately after the usual crushing operation, as it comes from the furnace, and which, still at a temperature of 212° to 250° F., is conveyed to a bath of petroleum residues, where it remains about five or ten minutes. It is then withdrawn and allowed to drain. When thus treated, it is said that the carbide is not affected by atmospheric moisture, whereas with a body of water it decomposes very slowly at first, but with increasing rapidity "as the particles are laid bare." W.

ARTIFICIAL AND NATURAL INDIGO.

The commercial production of artificial indigo by the Badische Anilin u. Soda Fabrik, has aroused the greatest interest in the textile world, and has caused much attention to be devoted by chemists to the composition and properties of the natural product.

It has been shown that natural indigo constantly contains, besides indigotin and mineral matters, indirubin, indigo-brown, and indigo-gluten.

As the synthetical indigo is pure indigotin, it is a matter of some importance to determine whether the other incidental constituents of the natural product possess properties of value in dyeing, in order to ascertain the comparative value of the two products.

The results of the exhaustive study of the natural product by MM. Schwarzenberg and Schwartz appear to establish the following facts of value.

(1) The greater part of the indigo-gluten passes into solution in the indigo vat; a small quantity remains in the vat—sediment. This constituent of the natural product is without influence in dyeing.

(2) Indigo-brown forms an insoluble compound with lime and remains in the sediment. This constituent, also, has no effect on indigo dyeing.

(3) Indirubin dyes, to some extent, but it increases neither the fastness nor the brilliancy of shade of the dye; the effect, indeed, of a large proportion of it, is to give a shade which is dull and unpleasing.

These conclusions, it is stated, have recently been fully confirmed by the Badische Anilin u. Soda Fabrik. These manufacturers declare, also, that the fastness to rubbing and washing of their new artificial indigotin, when dyed on cotton fabrics in the ordinary manner, is equal if not slightly superior, to that of natural indigo. They state, also, that the shade and fastness of indigo dyes are not influenced by indirubin, indigo-gluten, and other organic substances present in indigo, but that such modifications as may occur in these features are due to methods of setting and working the vats.

It will be of interest to notice, in conclusion, that the manufacturers above-named, state that they are in a position to produce, by a synthetical process, indirubin. W.

DAMAGE TO IRON VESSELS BY GALVANIC ACTION AT A DISTANCE.

An unusual and interesting case of galvanic action exerted at a distance is reported from an Italian source.

The captain of the port of Leghorn brought action in court against the owners of certain wooden yachts with coppered bottoms to compel them to remove their vessels from the neighborhood of a number of new war-ships and other vessels with iron or steel hulls lying in the same part of the harbor.

The *London Engineer* is authority for the statement that the iron vessels were damaged by galvanic currents set up from the copper bottoms of the wooden yachts. The fact of the damage to steel and iron ships having taken place and of its being due to this cause was clearly established before the court, and as a consequence the captain's order for the removal of the copper-bottomed wooden yachts from the Darsena harbor of Leghorn was supported by decree of the court.

The article proceeds to explain that the galvanic contact in this case was established by the ropes which were made fast to different buoys in the basin, but this explanation is quite unnecessary, as the sea water forms a sufficiently good electrolytic conductor. W.

LIQUID FLUORINE.

Messrs. Moissan and Dewar have succeeded in liquefying this element, and publish some interesting facts respecting the liquid. Thus, its boiling-point was ascertained to be about 187° (Centigrade) below zero, and at 210° below zero, it showed no signs of solidifying.

If air be admitted to the liquid it is instantly liquefied, producing in the tube two layers—the upper one colorless, of larger size; the lower one, of a pale-yellow, being fluorine.

In order to determine the density of the liquid, substances of known density were immersed in it after first being sufficiently cooled. It was found that wood, caoutchouc and ebonite floated on the liquid, while amber remained suspended. The density was thus determined to be about 1·14.

The intense activity of fluorine was strikingly shown by the circumstance that, even at the extremely low temperature of 210° (C.) below zero, hydrogen instantly combines with it with the production of great heat and light. Oil of turpentine explodes, when brought in contact with it, with a separation of carbon. A bottle of the liquid was accidentally spilled on the floor, when the wood caught fire. W.

ACETYLENE AS A POWER GENERATOR.

The recent annual meeting of the German Society of Gas and Water Experts in Nüremberg, was made the occasion for an exhibition of acetylene and its applications.

In reference to the application of this interesting product to the gas engine as a power generator, *Dingler's Polytechnisches Journal* has the following comments that will be read with interest by American engineers, to most of whom such application will doubtless be new:

The principal difficulty hitherto encountered in applying acetylene as a motive-power lay in obtaining a non-luminous flame—the evidence of complete combustion—without danger. This difficulty, our authority declares, is now overcome by the devices constructed by one of the Berlin acetylene companies.

It is stated, in the same connection, that acetylene is now applied in power generators (gas-engines) in the same manner as ordinary coal-gas and water-gas. In order to obtain the full output of the energy of the gas, it must be mixed with air in the right proportion to produce perfect combustion, which is indicated by a non-luminous flame. The power developed by the explosion of acetylene completely burned in the cylinder is said to be much greater than that obtainable with water-gas. W.

ELECTRICITY IN PAPER-MAKING.

The *Electrical World* reports that the Cumberland Mills, near Portland, Me., are operated by power electrically transmitted from a waterfall four miles distant.

The generating plant consists of two 300 horse-power dynamos coupled to 48-inch Victor vertical turbine. The alternating current system is used, the pressure being raised by transformers from 1,100 volts at the generators to 8,000 volts at the mills, where it is again reduced to 400 volts for supplying the motors.

The efficiency of the plant is found to be about ·76 per cent., from the brake horse-power of the turbines to that of the motors. A marked saving is said to be effected in comparison with steam-power. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, April 19, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 19, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 145 members and visitors.

Additions to membership since last report, 60.

The president made reference to the highly gratifying increase in the membership since the beginning of the present year, and urged the members to second the active efforts of the Committee on Membership.

Mr. A. E. Outerbridge, Jr., presented an interesting address entitled, "Notes of a Trip to the West Indies." The speaker gave an account of his observations made during a recent trip of several weeks to a number of these islands, with special reference to their industrial conditions. The subject was profusely illustrated with the aid of the stereopticon.

Mr. John Jerome Deery read a paper describing the "Improved Methods for the Purification of Sewage and Water," as exhibited by the operation of the municipal plant at Reading, Pa. The speaker described this important installation in detail, illustrating the same with lantern views. The subject was referred for investigation and report to the Committee on Science and the Arts.

Mr. John Forbes described and illustrated in operation several modifications of an improved "Apparatus for Sterilizing Water," by which it was claimed to be practicable to sterilize from 2,000 to 5,000 pounds of water by the expenditure of 1 pound of coal. The subject was likewise referred to the Committee on Science and the Arts.

Adjourned. WM. H. WAHL, *Secretary.*

ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE FOR THE SESSIONS 1898-1899.

The number of students this year has been 26 per cent. greater than last year, showing what a good indication the school gives of the condition and prospects of the mechanical interests of the city. Very few come to this kind of a school who do not possess mechanical instincts which they desire to develop. They are either connected with some industry or desire to be, or they would not make the sacrifice necessary to learn this very important requisite. This feeling is a most promising thing for the country. The value of it was forcibly shown in the recent war with Spain, particularly in the naval engagements, where the forethought, care and mechanical knowledge and instincts of our officers and men won such signal victories over the intrigues, diplomacies and vanities of the Spaniards. It is to be hoped that this condition will continue and increase, and that the great majority of our youth will be interested in physics, mathematics and mechanics, so that when emergencies arise they will be powerful to meet them. All institutions that tend to develop this condition should be fostered and encouraged, and young men should understand that, in whatever position circumstances and fortune have placed them, they should not neglect to cultivate, to some degree at least, a knowledge of mechanics and the laws which govern material things. My experience in teaching in this school has clearly shown me the great difference in human natures in this regard. The experience, associations and inheritance of one student has so influenced his mind that he can quickly and clearly conceive of the relations of lines, surfaces and solids in the abstract, while another student, with different gifts has great difficulty in understanding them even in the concrete. But time, thought and training almost always overcome this difference to a great extent, and in many instances the improvement has been something remarkable, the most unpromising cases at the beginning ranking among the best at the end. This has often proved to me the wisdom of the system of individual instruction that we use, modifying the course and the speed to suit the character of each case. Of course, many enter the school who have not the quality of mind, the instincts or the patience to ever take sufficient interest to profit by it, but most of these go no farther than the first term, and it is safe to assume that all who graduate have received what will be of great value to them in life, even though they may never after make a drawing. They have received an impulse which will tend to develop in them such qualities as made the difference between the handling of the ships and guns of the Americans and the Spanish.

The school is conducted for the benefit of the students, but to receive this benefit in its full extent, requires the full amount of effort on their part. As a rule they make this effort and receive the benefit, and I have yet to hear of a graduate who regretted the time and work spent here.

Wm. H. Thorne, *Director.*

The following Students are Entitled to Honorable Mention:

In the Senior Mechanical Class.

John Kleische,
Frank F. Schauer,
Paul E. Hottinger,
William W. Hodge,
Harry C. Brinton,
Walter Arnaiz,
George F. Eisenhardt.

In the Intermediate Mechanical Class.

William Williams,
Otto Glein,
William Hall,
Charles G. Shafer,
Samuel Greenlee,
Victor Johnson,
Philip Marratt.

In the Junior Mechanical Class:

Harry Collins,
Thomas Yapp,
James B. Stevenson,
Harry Gray.

In the Architectural Class.

Roy E. Blithe,
William H. Gould,
Charles Ritzel,
George Dewees,
George Eiselé.

In the Free Hand Class.

Robert F. Plum,
Edwin McCausland.

The following Students are Awarded Scholarships from the B. H. Bartol Fund, entitling them to Tickets for the next Term:

Harry Thompson,
Frederick Schwartz,
Frank H. Stiffel,
Herman H. Langefeld,
George J. Wolf,
Alfred Whitney, Jr.

The following Students, having attended a Full Course of Four Terms with satisfactory results, are awarded Certificates:

William Bergman,
Harry C. Brinton,
Christian H. Clausen,
Emil P. Hottinger,
John Kleische,
Edward V. McCaffrey,
Owen F. Mullen,
John Wright Reeve, Jr.,
Charles P. Richter,
Charles Ritzel,
Alexander Stevenson,
Frank H. Stiffel,
Harry Thompson,
Lawrence Verga,
Alfred Whitney, Jr.,
George J. Wolf,
Paul W. Zook;

and from the Branch School at Germantown Junction:

Walter L. Fitzgerald, Howard Beeson,
Elwood F. McLaughlin, Edward Gunderman,
William K. Harris.

ADDITIONS TO MEMBERSHIP.

JANUARY 1 to MARCH 31, 1899.

The following persons have been elected and qualified as members of the Franklin Institute during the three months beginning January 1st and ending March 31, 1899:

ABBOTT, A. V., Chief Engineer Chicago Telephone Co., 203 Washington street, Chicago, Ills.

ANDERSON, FRANK, Mining Engineer, 255 Second East street, Salt Lake City, Utah.

ARMITAGE, GEORGE T., Mechanical Engineer, 108 Girard Building, Philadelphia, Pa.

ARMSTRONG, E. J., Mechanical Engineer, care Ames Iron Works, Oswego, N. Y.

AYER, JAMES I., Manager, 5 Main street, Park, Malden, Mass.

BABCOCK, STEPHEN E., Chief Engineer Water Works, Little Falls, N. Y.

BACHMAN, F. E., Manager Buffalo Furnace Co., 62 Highland avenue, Buffalo, N. Y.

BAKER, CHARLES F., Superintendent Motive Power and Machinery, 439 Albany street, Boston, Mass.

BECK, Matthias A., Mechanical Engineer, 160 Clinton street, Milwaukee, Wis.

BEDELL, FREDERICK, Ph.D., Assistant Professor Physics, Cornell University, Ithaca, N. Y.

BELCHER, A. W., Superintendent Repair Shops, Cornell Steamboat Co., Rondout, N. Y.

BELLINGER, H. C., Metallurgist and Chemist, Northport, Wash.

BERDELL, THEODORE, Metallurgist, 100 Broadway, New York, N. Y.

BERLINER, E., Electrical Inventor, 1717 P street, Washington, D. C.

BIERWIRTH, L. C., Secretary New Jersey Iron Mining Co., Dover, N. J.

BIRD, WILLIAM W., President Broadway Foundry Co., Cambridgeport, Mass.

BLACKBURN, A. H., M. E., General Manager The Fuel Economizer Co., Matteawan, N. Y.

BLISS, WILLIAM L., Inventor of Bliss Electric Car Lighting System, 128 Front street, New York, N. Y.

BOILEAU, WILLARD E., Electrical and Mechanical Engineer, Columbus, Ga.

BREWSTER, FRANK H., Superintendent and Engineer Birmingham Iron Foundry, P. O. Box 418, Derby, Conn.

BRILL, GEORGE M., Managing Engineer of Swift & Co., 444 W. Sixty-fifth street, Chicago, Ill.

BRINLEY, CHARLES A., Manufacturer, 247 South Sixteenth street, Philadelphia, Pa.

BROOKS, MORGAN, Professor Electrical Engineering, University of Nebraska Lincoln, Neb.

Brown, Charles Sumner, Professor Mechanical Engineering, Vanderbilt University, Nashville, Tenn.

Bush, Harold M., Mechanical Engineer, "The Dennison," Columbus, O.

Burke, M. D., Civil Engineer, 404 Pike Building, Cincinnati, O.

Cake, H. W., Assistant Superintendent of Stamp Mills, Calumet and Hecla Mining Co., Lake Linden, Mich.

Calvert Louis L., Architect, 1604 Real Estate Building, Broad and Chestnut streets, Phila., Pa.

Cambier, Jacob, Chemist Colorado Fuel and Iron Co., Pueblo, Colo.

Canfield, Frederick A., Mining Engineer, Dover, N. J.

Capp, John A., Mechanical Engineer, 225 Union street, Schenectady, N. Y.

Christie, Wm. Wallace, Consulting Mechanical Engineer, Paterson, N. J.

Clement, Lewis M., Civil Engineer, 1013 Twelfth street, Oakland, Cal.

Coffin, Charles E., Pig Iron Manufacturer, Muirkirk, Md.

Colwell, James M., Assistant Cashier, Kittanning, Pa.

Comly, George N., Mechanical Engineer, Solvay Process Co., 1816 West Genesee street, Syracuse, N. Y.

Conradson, P. H., Chief of Bureau of Tests Galena Oil Co., Franklin, Pa.

Cook, Edgar S., President Warwick Iron Co., Pottstown, Pa.

Cooper, Henry R., Solvay Process Co., 1921 W. Genesee street, Syracuse, N.Y.

Cox, J. D., Jr., Manager Cleveland Twist Drill Co., Cleveland, O.

Crowell, Luther C., Mechanical Engineer, 504 Grand street, New York, N. Y.

Daggett, H. M., Jr., Electrical Engineer, care Welsbach Light Co., Gloucester, N. J.

Davis, F. Harley, Vice President Davis Calyx Drill Co., 203 W. One-Hundred-and-Seventeenth street, New York, N. Y.

Deans, John Stirling, Civil Engineer, Phœnixville, Pa.

Dodds, E., Superintendent Chandler & Taylor Co., 2013 E. Tenth street, Indianapolis, Ind.

Doney, Dewitt C., Chemist and Assayer, 1189 Fairfield avenue, Bridgeport, Conn.

Eavenson, Alban, Chemist, 320 N. Twentieth street, Phila., Pa.

Emerick, Lewis W., Electrical Engineer, care Solvay Process Co., Syracuse, N. Y.

Ewer, Rowland G., Mechanical Engineer, 119 Halsey street, Brooklyn, N. Y.

Fingal, Charles A., Mechanical Engineer, Stewart avenue and Twenty-third street, Chicago, Ill.

Fish, Charles H., Agent Cochico Manufacturing Co., Dover, N. H.

Foster, Eugene C., Instructor of Physics and Chemistry Temple College, Phila., Pa.

Fritz, John, Mechanical Engineer and Manufacturer, South Bethlehem, Pa.

Fryer, George G., Mechanical Engineer, Solvay Process Co., Syracuse, N. Y.

Gillis, H. A., General Superintendent Locomotive Works, Richmond, Va.

Gleaves, Taylor, Consulting Engineer, Lynchburg, Va.

Glenn, H. F., General Manager, Jackson & Woodin Manufacturing Co., Berwick, Columbia Co., Pa.

Golden, M. J., Professor Practical Mechanics, Lafayette, Ind.

GOLDSBOROUGH, W. E., Professor Electrical Engineering Purdue University, Lafayette, Ind.

GOLDTHWAIT, ABEL G., Mechanical Engineer, 181 Eighth street, Troy, N. Y.

GREEN, GEORGE ROSS, Mechanical Engineer, 418 School Lane, Germantown, Pa.

GREEN, THOS. W., Superintendent Wilbraham-Baker Blower Co., 2518 Frankford avenue, Phila., Pa.

GUBELMAN, FRED J., Engineer, 792 Montgomery avenue, Jersey City, N. J.

HAND, HARRY W., Superintendent I. P. Morris Co., 1800 N. Sixteenth street, Phila., Pa.

HARKNESS, WILLIAM, Professor Mathematics U. S. Navy, U. S. Naval Observatory, Washington, D. C.

HARRIS, IRA, Marine Superintendent, U. S. A. T. Service, Army Building, New York, N. Y.

HAYNES, WM. L., Mechanical Engineer, 120 Durham street, Mt. Airy, Phila., Pa.

HENDERSON, J. C., Mechanical and Electrical Engineer, 11 Broadway, New York, N. Y.

HENNEY, J. B., General Manager Hartford Light and Power Co., 90 Vernon street, Hartford, Conn.

HEPBURN, FRANK, Extract Manufacturer, Jacksonville, Fla.

HERR, EDWIN M., Assistant General Manager Westinghouse Air-Brake Co., 271 Shady avenue, Pittsburg, Pa.

HERSCHEL, CLEMENS, Hydraulic Engineer, 2 Wall street, New York, N. Y.

HILL, GEORGE, Architect and Consulting Engineer, 44 Broadway, New York, N. Y.

HILLS, A. H., 23 California street, San Francisco, Cal.

HOE, ROBERT, Engineer and Manufacturer Printing Presses, 504 Grand street, New York, N. Y.

HOLLINGSWORTH, SUMNER, Engineer and Paper Manufacturer, 60 India street, Boston, Mass.

HOWARD, JOHN L., Manager Pacific Coast Co., Vernon Heights, Oakland, Cal.

HUMPHREY, JOHN, General Manager Humphrey Machine Co., 400 Main street, Keene, N. H.

HUMPHREY, RICHARD L., Chemist, Testing Laboratory Department of Public Works, City Hall, Phila., Pa.

HUNT, ALFRED E., Manufacturer and Civil Engineer, 4916 Wallingford street, Pittsburgh, Pa.

JACOBUS, D. S., Professor Experimental Mechanics Stevens Institute, Hoboken, N. J.

JEWELL, C. W., Mechanical Engineer, Beaufort, S. C.

JONES, FORREST R., Professor Machine Design University of Wisconsin, Madison, Wis.

JONES, W. CLYDE, Lawyer, 100 Washington street, Chicago, Ill.

JOST, J. F. W., Chemist, care Welsbach Light Co., Gloucester, N. J.

KELLER, E. E., Vice-President Westinghouse Machine Co., East Pittsburgh, Pa.

KIEFER, H. E., Analytical Chemist Lehigh University, South Bethlehem, Pa.

KUNZ, FRED. C., Bridge Engineer, Pencoyd Iron Works, Pencoyd, Pa.

LAMOTTE, ARTHUR, Chemist, Chester, Pa.

Leisen, Theodore A., Civil Engineer, Wilmington, Del.

Leonard, Arthur G., Assistant to Superintendent of Motive Power and Rolling Stock N. Y. C. & H. R. R. R., Grand Central Depot, New York, N. Y.

Lobben, Peder, Mechanical Engineer, 14 Leighton street, Fitchburg, Mass.

Loomis, F. J., Chief Engineer, 126 Chestnut avenue, Waterbury, Conn.

Loring, Charles H., Chief Engineer U. S. N., 239 Clermont avenue, Brooklyn, N. Y.

MacNutt, Barry, Electrical Engineer, Assistant Inspector of Ordnance U. S. A., 27 S. Linden street, South Bethlehem, Pa.

Mailloux, C. O., Electrical Engineer, 48 W. Seventy-third street, New York, N. Y.

McKee, Joseph J., Mechanical Engineer, Bethlehem, Pa.

Mellen, Edwin D., Soap Manufacturer, 1590 Massachusetts avenue, Cambridge, Mass.

Moore, R. S., Superintendent Risdon Iron Works, Howard and Beall streets, San Francisco, Cal.

Muller, E. A., Superintendent Springfield Machine Tool Co., 26 Miller street, Springfield, O.

Mumford, Edgar H., Secretary and Treasurer The Taber Manufacturing Co., Plainfield, N. J.

Murray, T. J., M.D., Physician and Surgeon, Butte, Montana.

Newcomer, Harvey, Instructor University of Pennsylvania, 4116 Spruce street, Phila., Pa.

Norris, R. V., Mining Engineer, 24 S. Franklin street, Wilkes-Barre, Pa.

O'Neill, Emmet, Plumber and Gas Fitter, 4223 Frankford avenue, Phila., Pa.

O'Neill, H. Gibson, Electrical Engineer, and Electro-Therapist, 11 W. Thirty-ninth street, New York, N. Y.

Ottens, Henry H., Manufacturing Chemist, 123 S. Water street, Phila., Pa.

Paul, John Wallace, Superintendent Pittsburgh Writing Machine Co., Kittanning, Pa.

Pettit, John Read, Student, Delta Phi House, South Bethlehem, Pa.

Phillips, John L., Salesman, 1921 Vine street, Phila., Pa.

Platt, John, Mechanical and Marine Engineer, 99 Cedar street, New York, N. Y.

Rand, Addison C., President Rand Drill Co., 400 West End avenue, New York, N. Y.

Rice, Isaac L., President Electric Storage Battery Co., 20 Broadway, New York, N. Y.

Richards, Francis H., Mechanical Engineer and Patent Attorney, Hartford, Conn.

Robinson, Samuel Adams, M.D., West New Brighton, Staten Island, N. Y.

Rodgers, Howard S., Electrical Engineer, 420 W. Fourth street, Cincinnati, O.

Rowland, Charles Bradley, Civil and Mechanical Engineer, care Continental Iron Works, Brooklyn, N. Y.

Schumann, George, Superintendent Scott Foundry Department Reading Iron Co., Reading, Pa.

Shankland, E. C., Civil Engineer, 816 Rookery, Chicago, Ill.

Shaw, E. C., Mechanical Engineer, 104 Park street, Akron, O.
Stanton, F. McM., Agent of Copper Mines, Atlantic Mine, Houghton Co., Mich.
Stanton, J. R., Treasurer Copper Mining Co., 11–13 William street, New York, N. Y.
Stearns, Chas. K., Mechanical and Electrical Engineer, Room 808, 60 State street, Boston, Mass.
Steinmetz, Edward G., Assistant Superintendent Electric Storage Battery Co., 1609 N. Fifteenth street, Phila., Pa.
Stern, Wm. A., Electrical Engineer, 401 Drexel Building, Phila., Pa.
Stevenson, A. A., Mechanical Engineer, Burnham, Pa.
Stewart, Ralph C., Student, 1031 Spruce street, Phila., Pa.
Symons, W. E., Superintendent Motive Power Plant System, Savannah, Ga.
Taylor, Stevenson, Marine Engineer and Boiler Builder, Hoboken, N. J.
Thompson, Edwin W., Mill Engineer, Charlotte, N. C.
Tigerstedt, A. F., Mining Engineer and Director Iron Works and Mines, Helsingfors, Finland.
Waitt, Arthur M., General Master Car Builder L. S. & M. S. Ry., Cleveland, O.
Walker, John, Mechanical Engineer, 635 Jackson Boulevard, Chicago, Ill.
Wallis, Phillip, Master Mechanic, L. V. R. R. Co., Easton, Pa.
Weeks, Edwin R., General Manager Edison Light and Power Co., 1409 Cherry street, Kansas City, Mo.
Werner, D. T., Ph.D., Chemist Liquefied Acetylene Supply Co., Lebanon, Pa.
Wheeler, F. Merriam, Secretary The George F. Blake Manufacturing Co., 91 Liberty street, New York, N. Y.
White, Horace M., Dentist, 1616 Chestnut street, Phila., Pa.
Whyte, F. M., Mechanical Engineer Chicago & N. W. Ry. Co., 225 Dearborn street, Chicago, Ill.
Wild, Charles E. (Retired), Mulhouse, Alsace.
Williamson, R. B., Mechanical Engineer, Instructor Lehigh University, 440 Cherokee street, South Bethlehem, Pa.
Willis, Warren E., Mechanical Engineer, 109 N. Twenty-second street, Phila., Pa.
Wilson, James C., M.D., 1437 Walnut street, Phila., Pa.
Wolf, Theo. R., State Chemist of Delaware, Newark, Del.
Wolverton, B. C., Electrician Electrical Department N. Y. & Penna. Telephone and Telegraph Co., Elmira, N. Y.
York, H. W., Chief Engineer United Electric Light and Power Co., 108 Fulton street, New York., N. Y.
Zerr, G. B. M., Instructor Department of Science Chester High School, Chester, Pa.
Ziegler, S. Lewis, Physician, 1509 Walnut street, Phila., Pa.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held April 5, 1899.*]

PROF. EDGAR MARBURG in the chair.

The following reports were considered:

Improvements in the Art of, and Apparatus for, Combustion.—Paul J. Schlicht, New York.

ABSTRACT.—The *Sub-Committee* made a preliminary report, setting forth that it had been found impracticable thus far to arrange for a suitable investigation of the merits of applicant's system and apparatus, under its own direct observation and command in the vicinity of Philadelphia, and suggesting a postponement of the investigation until such time as applicant should be able to comply with the sub-committee's requirements.

The report was adopted. [*Sub-Committee.*—Chas. James, Chairman; Thos. P. Conard, Spencer Fullerton.]

Engine Valve.—Alexander G. Hay, Philadelphia, Pa.

ABSTRACT.—The invention is the subject of letters-patent of the United States to Alexander G. Hay, No. 603,380, dated May 3, 1898.

The report is to the effect that applicant has proceeded on the assumption that the saving of room, in the case of a marine engine, was the most important feature to be considered. He has, therefore, conceived the idea of making the valve surround the cylinder, thus occupying a thin annular space. In so doing, however, the investigating committee believes that he has overlooked all the other essentials of a practical valve. The diameter of the valve becomes necessarily larger than that of the cylinder, and, therefore, becomes more cumbersome than existing forms. The keeping of the valve in alignment and avoiding binding, as well as packing the valve satisfactorily on convex and concave surfaces, are difficulties introduced by this construction, which, in the judgment of the examiners, are insurmountable. The statements of applicant in relation to losses due to clearance in existing engines, the examiners find to be erroneous. The report concludes that the invention has no practical value. [*Sub-Committee.*—Arthur Falkenau, Chairman; H. W. Spangler, L. F. Rondinella.]

Machine and Cutter for Generating Gear-Teeth.—E. R. Fellows, of Springfield, Vt.

ABSTRACT.—The Fellows gear shaper is a machine designed to generate a complete set of interchangeable gears from a single cutter, which is in form similar to one of the gears produced.

It consists essentially of a frame, or housing, adapted to carry the gear-blank and the cutter-slide in proper relation to each other, and connecting mechanism whereby the gear-blank and the cutter are caused to roll together on their pitch lines, while the latter reciprocates, like a shaping tool, and cuts away the material presented to it in the wheel blank.

For details of the operative features of the invention and its scope and limitations, reference is made to the report.

The invention is the subject of letters-patent of the United States to E. R. Fellows, No. 597,708, March 30, 1897, and No. 579,570, of even date.

The report concludes with the statement that the Fellows machine and cutter for generating gear-teeth mark a distinct advance in the art of gear cutting which should be recognized by the award of the John Scott Legacy Premium and Medal. [*Sub-Committee.*—Wilfred Lewis, Tinius Olsen, Arthur M. Greene, Jr.]

Mr. Edward J. Moore presented a protest against the Committee's report in the case of his marine boiler.

The protest was referred to the sub-committee.

SECTIONS.

(*Abstract of Proceedings.*)

CHEMICAL SECTION.—The special meeting and *conversazione*, inaugurating the "Photographic and Microscopic Branch of the Chemical Section," took place on Tuesday evening, April 4th. The proceedings consisted of a brief address by Dr. Joseph W. Richards, President of the Section, setting forth the objects of the new branch, and an inaugural address by Dr. Charles F. Himes, of Carlisle, Pa.

The exhibits displayed were numerous, and of a highly interesting character; they comprised, among others:

A series of portraits, by Mr. F. Gutekunst, Philadelphia.

A fine display of microscopes, by Joseph Zentmayer, Philadelphia.

A collection of ruled glass screens for photo-engraving, by Max Levy, Philadelphia.

A collection of flash-light photographs, lantern slides and prints, by Mr. H. Parker Rolfe, Philadelphia.

Specimens of prints from films manufactured by Mr. John Carbutt, Wayne Junction, Philadelphia.

An exhibit of color-photographs, made by the "McDonough process," shown and described by Mr. H. F. J. Porter, Bethlehem, Pa.

Projections of color-photographs and a number of microscopic objects, by Mr. F. E. Ives, Philadelphia.

A photo-micrographic apparatus for studying the structure of models, etc., by Mr. Fred. D. Maisch, Philadelphia.

A collection of microscopic enlargements of insects, by Mr. John G. Baker, Philadelphia.

Photo-microscopic apparatus and miscellaneous apparatus, by Williams, Brown & Earle, Philadelphia.

Microscopes, photo-microscopic outfit and optical apparatus, by Messrs. Queen & Co., Philadelphia.

Microscopes and appurtenances and miscellaneous optical apparatus, by Lentz & Co., Philadelphia, representing the Bausch & Lomb Optical Company, Troy, N. Y.

A collection of photo-chromographs, by Photo-Chromotype Engraving Company, Philadelphia.

Selections from the collection of physical apparatus bequeathed to the Section by the late M. Carey Lea.

The meeting was largely attended, and proved to be a most auspicious opening for the new branch. All the exhibits were of a highly interesting and instructive character, and were thoroughly enjoyed.

The duty of conducting the affairs of the branch was confided to an Executive Committee composed of Mr. F. E. Ives, Mr. Theo. D. Rand, Dr. Henry Leffmann, Mr. W. N. Jennings and Mr. Thos. S. Stewart, Jr.

Following is an abstract of the address of Dr. Himes.

"This occasion does not mark a new departure for the Franklin Institute. It has always been alert and prompt to recognize advances in photography, to test and investigate them, and in all suitable cases to bring them before the larger public in its hall. This has been done through members as individuals interested in this subject, many of them eminent. This new branch simply proposes the fuller utilization of the activity of these members by concentration and organization.

"It means in no way or degree conflict, or competition with any of the long-established and effective photographic societies for which Philadelphia is distinguished. It would be a misfortune of it did so. It is intended rather to supplement them. Whilst they may cover the whole field of photography, there are some things—many things indeed—which they must necessarily regard as incidental. These, this branch will make its primary consideration. They are especially interested in the Art of Photography, and the pictorial and esthetic character of its results; this will concern itself rather with the Science of Photography and its increasing scientific and industrial applications. They desire results the most successful in every particular; this will enjoin failures, upon explanation of which higher success may be built. In short, these organizations are not on conflicting lines; not, indeed, on parallel lines, but rather on the same line—where one ends the other begins, the one continuing the work of the other. The Chairman, in his opening remarks, did not too decidedly emphasize Scientific Photography as the object of this branch. And yet there may be fields of activity for it outside of restricted scientific work. To briefly indicate a few, there are the educational possibilities and relations of photography, that may properly be considered. The Franklin Institute is a most effective educational institution. Again, the Institute, whilst it encourages and assists scientific activity, does much also by directing it into profitable and productive channels. There is to-day much photographic energy, especially of amateurs, running to waste, and largely for want of direction, or even suggestion. The production of Photographic Records might be made to absorb some of this. In England they seem to be fully awake upon this subject. There are many pictures in almost every locality that to-day have a limited topographical interest, that may acquire value with lapse of a few years. There are others that could be sought out with the certainty that they would acquire interest. This may be said to belong properly to historical associations. But they are not necessarily photographic, and suggestion could properly come from this body with such recommendations as to processes, sizes, mounting, storing, etc., as photographic experts could give. A picture of the old bridge at Columbia, about a year before it was burned, during the war, has acquired an interest not in the thought of the speaker, when he took it, as a boy, by the old wet process, and long-forgotten, it was recognized in a magazine article, taken from a stray print.

"Photography in judicial procedure is another open field. Photography is in court, and it is there to stay. It is in under the rules of 'best evidence,' and the 'necessity of the case.' But its position is not well-defined. Whilst the evidence it affords is accurate, minute, complete and free from bias, the fact cannot but be recognized that it has limits of applicability and reliability. It can even lie and be made to lie. Questions of highest importance, and often of great novelty, and in increasing numbers will continually arise in regard to it. If this organization can contribute in any degree to its proper and creditable recognition by the courts, it may be of great service in the cause of justice. It might even become to a degree authoritative upon the scientific and technical aspects of such cases. In this connection a collection of reports of cases in which photography is employed in evidence in any way, suggests itself. With the arguments and decisions it might prove in a short time of great value, and might even entice the legal fraternity to the hall and library of the Institute.

"Without taking time to enumerate others, these will suffice to indicate something of the general character of the field of activity, beyond the strictly scientific, that seems to open up before this branch. It is a matter of congratulation that it has opened so auspiciously, and the effort of all should be to keep it at least fully abreast of all the advances of a rapidly expanding branch of science."

Stated Meeting, Tuesday, April 18th, Dr. Richards in the chair.

Dr. Harry F. Keller, Dr. Robert Bradbury and Prof. E. A. Partridge were appointed as a special committee to select and report to the Library Committee, from time to time, the titles of books and periodicals relating to physics and chemistry, to be purchased with the income of the M. Carey Lea Fund.

Prof. E. A. Partridge presented a paper on "Series in Spectra," giving a very comprehensive summary of the development of scientific opinion on the subject.

The thanks of the meeting were offered to the speaker, and the paper was referred for publication.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, Wednesday, April 12th, President, James Christie, in the chair.

Mr. Paul Kreuzpointner, Testing Department Pennsylvania Railroad, Altoona, Pa., read a paper entitled "Riddles Wrought in Iron and Steel," illustrated with several photo-micrographs of the same specimens of steel, which exhibited the differences in structure caused by differences in the heat treatment to which the test pieces was subjected. The paper was discussed by Messrs. Webster, Outerbridge and the author, and was referred for publication.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, Thursday, April 13, Mr. James Christie, chairman *pro tem.*

The evening was devoted to the discussion of "Pumping Machinery; its Construction and Operation." The debate was opened by Mr. John Birkinbine, and was participated in by Messrs. J. J. De Kinder, John E. Codman and others.

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Mining and Metallurgical Section.

Stated Meeting, March 8, 1899.

SOME FEATURES OF THE STRUCTURAL DESIGN OF BUILDINGS.

BY WM. H. BURR,
Columbia University, New York.

Building construction in our largest cities has for some time passed the stage at which the necessity first arose to give it the thorough technical consideration which civil engineers give to all their structural work. This observation is true both of the superstructure of the building and its foundations. It was but a short time ago, not more than fifteen or twenty years, that foundation questions in ordinary cases were of minor importance. Almost any reasonable foundation construction, which might have been designed by any intelligent mason or masonry constructor, would have been sufficient for any building located on comparatively firm soil or sand. It is nearly as true, but not quite, that almost any reliable building constructor could have designed the structural part of the superstructure of the building with reasonable expectation of its being safe and suitable so far as its strength was concerned for the reception of any loads which might be put into it. It is for these reasons that the present building laws of all large cities are in such an excessively unsatisfactory condition. The greater part of the ordinances now in force were designed to meet the situation as I have just described it. The structures were not more than five or six stories in height at most, and few of them were expected to carry heavy loads, while none of them were fire-proof.

All this is now radically changed. Our tallest buildings reach a height of about 400 feet above the pavement, and the occupied portions of buildings are nearly thirty stories in height. The own weight of such buildings is sufficient to impose upon the foundations loads per square foot as high as it is safe to place on foundation supports designed and built under the most competent engineering supervision. Similarly the supports of the superstructure of the building, including beams, girders and columns must be designed so as to reach the highest engineering excellence attained in the structural practice of the civil engineer. The tall office buildings of the present day, commonly known as sky-scrapers, are now carried on frameworks of steel which form a component part of the building itself. The great height to which these buildings rise make it imperative that wind loads should be considered in their design as well as those which act in a vertical direction. Concisely put, the structural design and the construction of a modern high building requires the application of the most advanced engineering principles and neither superstructure nor foundation can be satisfactorily designed or constructed except under the best engineering supervision, from the main features to the smallest details.

In considering those features of building construction to which attention will be directed, it is most suitable to begin with the foundation. It is probably not far wrong to state broadly that the foundations of heavy buildings may be divided into three classes:

(1) Those which rest directly upon the earth or sand at the bottom of the excavation.

(2) Those which rest upon piles driven in groups under suitable portions of the structure.

(3) Those which are typified by the pneumatic caisson. That is, those in which the foundation structure is carried down to bed rock or its equivalent.

It would at sight appear that the first class is the simplest, yet many complicated questions may easily arise in connection with it. These earth foundations, as they may be called since the foundation bed is either earth or sand, must be so designed that the concentrated loads representing the supporting forces of the superstructure may be distributed from the points of concentration over such an area that the greatest allowed pressure per square foot on the earth shall not exceed a value which experience has shown to be safe either in respect to settlement or movement of the supporting material. Approximately speaking, it may be stated that the maximum working pressures allowable range from 4,000 to 8,000 pounds per square foot.

The means used for the distribution of these concentrated loads about the points of support are of considerable variety, but two methods have been largely employed. One, the older, being the inverted arch, and the other involving the use of courses of steel I-beams. The inverted arch was used for distributing the foundation pressures of the *World* Building in New York City. This building is a very high and heavy one, and its weight is carried on wrought iron columns down to masonry pedestals, which form the abutments of inverted arches of concrete. These inverted concrete arches are loaded in an upward direction by the pressure of the sand foundation bed. These arches obviously will be groined in regular or irregular series according to the location of the columns. It is a very satisfactory method of construction when the supporting earth or sand is in a suitably firm condition, and it affords an effective method of distributing the concentrated building loads. Obviously, however, it is not adapted to the softer materials which may flow under pressures no higher than those ordinarily permitted on firm earth or sand, and, furthermore, it will not usually prove to be an economical system in cost.

Another excellent method of distributing concentrated foundation loads over a bed of sand or other firm material is instanced by the foundation of the St. Paul building in New York City, one of the more recent high buildings. In this case the bottom of the excavation is covered by a thick plate of concrete. In this plate of concrete are embedded groups of steel beams so arranged as properly to meet the imposed loads of the superstructure. These steel beams may at many points be continuous under two or more column loads, and there may be one or two or more layers of beams arranged at right angles to each other in order to distribute the imposed loads with desired uniformity. It is only necessary so to arrange the distributing beams or girders as to make it reasonably clear by calculation that the imposed loads do not exceed safe limits, as prescribed either by building ordinances or by the specifications which govern the work, such maximum limit being, perhaps, 8,000 pounds per square foot. Other methods of distribution over an earth or sand foundation bed have been used, but the two described are certainly as good as any and typify excellently this class of foundation work.

The second class of foundation supports, consisting of piles driven in the bottom of the excavation to a more or less solid stratum, has been widely employed, and has given very satisfactory results under reasonably good design and execution. Groups of piles, 2½ to 3 feet apart centers, are driven under points of column loading in such number that the load on no pile will carry more than the prescribed limit, which is 20 tons in New York City, and as much as 25 tons in some places, the assumption being made that the piles carry the entire load. It is then customary to excavate around the heads of the piles to a depth of 1 to 2 feet and fill concrete into and above the excavation to a depth of at least 1 foot over the tops of the piles. On the concrete footing thus formed courses of steel rolled beams are placed at right angles to each other if more than one course is used. These rolled beams support the pedestal of the column above them, and they should be carefully protected by water-proof courses from any water that may find its way around the foundation. The spaces between the rolled beams and around their ends are carefully filled with hydraulic cement mortar or concrete, the beams themselves first being thoroughly painted. The groups of piles and the courses of steel beams with the concrete footing may be continuous under two or more columns. The design of these distributing beams, so as to carry their loads without subjecting them to higher fiber stresses than are prescribed, is now well known and thoroughly understood. The upward pressure on the bottom surface of each course of beams should be taken as uniformly distributed and not concentrated along opposite edges as has sometimes been done. This system of foundations, therefore, is capable of being designed with the same degree of definiteness that is required to satisfy any advanced engineering work at the present time. As a matter of fact, after the foundation is completed, the total loads are undoubtedly divided to some extent, at least, between the supporting piles and the earth or sand surrounding them and underneath the concrete. It is for this reason that comparatively high loads may safely be placed on the piles, and, furthermore, it may be stated that it is the chief reason why settlement does not take place with the miserably small piles frequently used in the foundations of buildings. These piles are often not more than 8 or 10 inches in diameter at the butt and 5 inches at the tip, with a length of anywhere from 18 to 25 or 30 feet. Twenty tons upon such a pile would make an excessive load if the pile should really carry it. The practice of using these so-called "toothpick" piles for heavy building construction is in the highest degree reprehensible and should not be permitted. The system as a system is an excellent one, but it is like any other system, in that it must not be abused if its results are to be satisfactory, and one of the most frequent and grossly inexcusable abuses is that resulting from using small sticks as piles which are absurdly inadequate to carry their nominal loads.

The third class of foundations cover those constructions which reach down from the pedestal of the column supporting the building to bed rock, or its equivalent. The pneumatic caisson has been more frequently used for this purpose than any other type of construction, although so-called hydraulic caissons or cylinders have been used in several instances in New York City. The pneumatic caisson consists of a box or cylinder, closed on all sides but one, the open side forming the bottom as it is used in sinking. Above this caisson is extended the vertical sides of the box or cylinder, and in the interior of this box or cylinder is carried a shaft fitted with suitable valves and other details, so as to form a closed portion called the air lock. The caisson has a roof, 7 to 8 feet above its lowest or cutting edge, forming a chamber in which men may work. The shaft just mentioned leads into this working chamber, and the air lock is placed at some point above the chamber. Compressed air from air compressors continually running, is forced into the working chamber and into the air lock at a pressure determined by the depth of excavation. This air pressure expels all water from the working chamber when the cutting edge is below water level, and enables the men to perform the operations required in sinking the caisson to any desired depth. The excavated material from the working chamber is sometimes forced out by the air pressure through small pipes, or is loaded into buckets and hoisted through the lock and shaft by the manipulations of appliances which prevent the escape of any sensible amount of compressed air. The caisson is sunk in the manner described until its lower edges reach bed rock or other hard material, the cylinder in the meantime having been loaded with pig iron or other heavy weights, which force it down against the upward pressure of the air and the friction of the material on its sides as the excavation is made in the working chamber. After the desired depth is reached, the rock is carefully cleared or cleaned of all soft material, and the working chamber is filled with concrete by the men as they finally withdraw from it. The air lock is then removed and sometimes a portion of the shaft. The remaining portion of the shaft and the volume of the cylinder outside of it are then filled with hydraulic cement concrete to its top. If desired, a stone capping may be placed upon the cylinder to receive the pedestal under the column above it. By this means the support of the building is carried directly to bed rock or its equivalent. These caissons, either rectangular, circular or oblong in horizontal section, may be of any size, from a diameter just large enough to allow one man to work, up to dimensions large enough to receive two or more columns.

Circular cylinders have also been sunk by fitting jets or nozzles to their lower edges and forcing water through them under a comparatively high pressure. The escaping water washes away the sand and other material and allows the cylinder to sink into the annular space thus made free of sand or earth. After the cylinder has been sunk to the required depth the water is kept pumped out from its interior and the sand or earth is thus excavated in the dry. As the excavation proceeds the cylinder is braced internally, so as to prevent collapse until the bottom is reached. The bottom is then properly prepared to receive concrete, with which the interior of the cylinder is filled, the braces being removed as the concrete filling is completed.

Much has been said and written about the superiority of carrying foundation supports to bed rock. It is undoubedly satisfactory to have foundation supports carried down to rock, but it is difficult to see wherein the pile foundation fails to answer an equally satisfactory purpose when properly designed and executed. The metallic portions of pneumatic caissons and hydraulic cylinders will, within a period not by any means indefinitely long, corrode and disappear. Under proper design this is not a serious feature of the matter, but it is a feature which demands that the concrete mass shall be made as nearly monolithic as possible without unnecessary divisions by metallic plates. On the other hand, if piles are used below the water level, as they should be, they are indestructible, and will, so far as we know, remain in place for all time. On the whole it would appear, both from rational considerations and from engineering experience to the present time, that the question of selection of either system of foundation may be based upon economical considerations only, the design and execution being assumed to be excellent in either case.

The type of superstructure, the features of which are to be considered, is that of which large buildings of the greatest heights are now constructed, and which involves a metallic framework carrying not only all the interior but the exterior walls also. This type is the latest development in the progress of building construction, although in view of the large number of buildings now constructed on its principles it can no longer be called a new type. The columns of the metallic superstructure were first made of cast iron, although at the time when this type of structure was first used by architects, civil engineers had already abandoned cast iron for long compression members and were using wrought iron columns. Practically, in the first stages of the modern metallic frame for high buildings, wrought iron columns were already in the field as compression members. These were followed by columns builts of rolled steel shapes, which now predominate in the best class of high buildings with few exceptions. In those instances in which cast iron columns have been used the prevailing sections are either rectangular or circular, although the rectangular form has been subject to a considerable number of essential variations. The sections are in the majority of cases closed, although a considerable number of columns of the I or H shape have been used. The sections of wrought iron and steel columns used in building construction are much more varied. Indeed, the number of different sections of rolled columns either of wrought iron or steel is very great, some being closed and others open. Although civil engineers have held strenuously to open columns in their bridge practice in consequence of the inaccessibility of the interior surface to the paint-brush the consensus of engineering opinion and practice has been such as to favor the use of the closed column in building construction. There are few exceptions to that observation. Columns in a building may be and usually are well protected against atmospheric influences, a condition radically different from that in which the column finds itself in a bridge structure. It has been maintained by architects of experience that the protection surrounding many of the exterior columns of buildings is not enough to prevent access of sufficient moisture to cause serious corrosion within a limited time. It may be an open question how much moisture and even rain water may be driven through the interstices of a comparatively thin brick wall, or even a concrete wall, in which a metallic column is embedded; but it is certain that when reasonable precautions have been taken, and where reasonably good design is found, any serious corrosion has not yet been established. It does not follow from these observations that we should not attempt to increase the security of our metallic construction in buildings against atmospheric effects. Indeed, it is undoubtedly true that this feature of modern building construction does not receive sufficient attention in many buildings which are considered to be of most excellent design. I believe it can be stated with confidence, however, when the metal work of the exterior columns of a building are well painted with three coats of paint, applied to thoroughly clean surfaces, and when these columns receive such protection as it is perfectly feasible to attain in modern building construction that the question of possible corrosion with the lapse of time is one of very subordinate importance. In other words, it is believed that at the present time the exterior columns of any building may be given practically complete protection against corrosion without resorting to features of building construction which are not already found in the best of present building practice. It may be assumed therefore that the admission of closed columns in building construction is wise and justified by experience.

There are certain well-defined requisites in any good column design that have long been recognized in engineering practice. In the first place it is essential that any column should be so made that practically all internal stresses may be eliminated, for if they exist obscure conditions arise which experience has many times shown to prejudice most seriously the resistance of the column. The cast iron column probably violates this fundamental condition in the most aggravated manner. The amount of internal stress in any cast iron column cannot bè assigned with any precision. It is only certainly known that it always exists, and that it frequently exists to a very serious extent. Columns built of rolled sections like those of wrought iron and steel, on the other hand, are practically free from internal stresses, or, at least, is is quite easy so to construct them as to reach that end, and they are usually so constructed.

Again, the metal of a column should be so distributed as to offer the greatest possible resistance to bending; or, to put this matter technically, the moment of inertia of the column section should be made as great as is feasible in those directions in which the column is likely to bend. With this judicious arrangement of metal in the cross section of the column it is imperative that its different parts shall be so secured to each other that there shall be no possibility of relative longitudinal motion; in other words, longitudinal shear must be resisted. Those parts should also be mutually supporting so that when the column fails it shall fail as a whole and not in detail. These fundamental principles are very simple in application and have long been recognized. Yet at the present time they are not always secured in some forms of columns quite frequently employed in building construction. While it is important to secure the features which have just been described in column design, it is at the same time essential that such forms of section be used as will permit of the construction of efficient details, particularly where beams and girders are attached to the columns. These details at the joints of the columns and at the points where beams and girders rest on the columns are among the most important features in the whole design of the metal frame. It is imperative, therefore, that the column section shall not only afford the desired resistance as a column, but also essential facilities for strong and rigid attachments of as simple character as is feasible. It is quite within reasonable limits of good structural practice at this time to attain all these desired ends in column design without any difficulties whatever, and at a reasonable unit price for the metal work. The details of attachment should be of such character as to insure the continuity of the column at the joints and also to insure the application of the load conveyed by the beams and girders practically at the center of the column. It is an old and frequent, but inexcusable offence in design, so to detail the different parts of a metal framework as to give to the loads an eccentric application to the column. In no practical case is it possible accurately to measure the eccentricity of an applied load. The result is a bending stress of unknown amount inadequately provided for, and which is added to the direct load of compression properly resting upon the column. It is essential to good design, therefore, that all eccentric application of wall or floor loads to columns be avoided, as is done in the best of building construction at the present time. That is, such results are reached in columns of structural steel, but they are not reached in the case of cast iron columns for the simple reason that it is practically impossible to do so. I say it is practically impossible to do so for the reason that too much labor and too much complication of detail is requisite in order to attain such ends. As a consequence, loads are almost invariably applied to cast iron columns on lugs or cantilever projections, the bearing surfaces of which are in the rough, precisely as they come from the sand. These details are invariably ill-fitting and crude in every respect so that the applied loads are just as likely to rest on the edge of the projection as anywhere else, and, in fact, a good deal more so. A few critical examinations only of the joints and lugs of cast iron columns, carrying loads, will satisfy almost any competent mind not already biased in favor of the cast iron column as to this point. These features of cast iron column practice are all the more inexcusable for the reason that it is the poorest of all structural metals to resist bending and tension. Indeed, it is structurally unpardonable to permit cast iron to be used in tension at all.

Whenever a cast iron column receives an eccentric load, and, unfortunately, it seldom receives any other, a considerable bending immediately takes place, and to such an extent that it is practically certain in many cases that one side of the column is subjected to tension.

It has been thought and maintained by many advocates of cast iron columns that they are more economical than either wrought iron or steel, although at the present time the question is one of cast iron against structural steel alone. As a matter of fact until within the past year, the computation of the carrying power of cast iron columns, as they are used in buildings, has been a matter largely of guesswork. Formulæ based upon the toy cast iron pieces, used by Hodgkinson in his historic tests fifty years ago, have been constantly employed in building practice. In 1889 a series of tests of full-sized columns was made in the large Emery machine at the U. S. Arsenal at Watertown, Mass., but the series was not sufficiently extended to make the results a basis for new formulæ. In 1896 and 1897, however, other tests, executed under the auspices of the Department of Buildings of New York City, were made in the 1,000-ton testing machine of the Phœnix Iron Company, at Phœnixville, Pa. The results of these tests and those made at Watertown, Mass., afford complete data for satisfactory formulæ for the resisting capacity of cast iron columns, although a considerable portion of them are more or less erratic. Those erratic results will not surprise any engineer who has had much experience with cast iron compression members. The failures of the columns usually took place at some point of defect. The columns were all circular in section and hollow, with thicknesses and general dimensions about as found in ordinary cast iron column practice. As in all such members, however, the thickness frequently varied considerably from one side of the column to the other, and gave rise to consequent weakness. Again, the records of the tests showed frequently such defects as "foundry dirt," or "honeycomb between inner and outer surfaces," "bad spots," "cinder pockets and blowholes," "flaws and foundry dirt," and so on to the end of the list. In other words, adventitious defects often determine failure and prevent carrying the load which sound metal and the desired distribution of it would enable the column to carry. As a result of these tests it is found that the ordinary cast iron column formulæ, which have generally been used in practice, credit the columns with just about twice as much load as they are able to carry for such lengths as are frequently used. Taking the entire range of lengths of columns permitted in ordinary practice, the formulæ commonly used make cast iron columns from once and a half to twice as strong as they actually are. That is, the safety factor is actually but one-half to two-thirds of its nominal value. If the results of these full-size cast iron column tests are plotted so as to be shown graphically the results which I have just described appear very evident. Such a graphical representation will also show that if the same degree of safety is secured by the use of cast iron columns as is reached in the use of structural steel columns, the cross-sectional area of the cast iron columns would have to be about twice that of the steel columns. Under such circumstances it is quite evident that the supposed economy of the cast metal would disappear. In fact, it may safely be asserted that if the same degree of safety is secured, the structural steel column will be the cheapest, as it is in all respects the best.

Although many high buildings are now erected alongside of or between other buildings for at least a part of their heights, and to that extent are protected from winds, yet wind bracing or substantial wind portals are an essential feature of every good steel frame design, nothwithstanding the fact that they are generally omitted. There are always times when tall buildings are subject to the action of high wind pressure. If they are then in course of erection the bracing or portals are necessary for safety, and they give the building desirable stiffness after completion. The frames of many tall buildings have been run up ahead of walls and partitions, carrying a considerable number of tile floors and tiers of columns absolutely unbraced laterally. It is amazing that a wind disaster has not overtaken a number of such cases. One or two at least have been blown so far out of plumb, that they have with difficulty been saved and brought back into position. Either bracing or portals can always be used; they cost little, and make the difference between certain stability in all conditions and possible failure in at least some.

[*To be concluded.*]

Special Meeting, March 23, 1898.

BUILDING-STONES—ELEMENTS OF STRENGTH IN THEIR CONSTITUTION AND STRUCTURE.*

By ALEXIS A. JULIEN,
Columbia University, New York.

(*Concluded from p. 397.*)

IV. RIGIDITY.

This property, in contradiction to the popular view, far from being characteristic of stone, is rather one of those to be specially sought after in a variety chosen for building purposes. A most desirable element of strength lies in internal immobility of grains or lack of plasticity; since any internal motion or change of relationship among these is likely to disturb the completeness of original interlockment, cementation and absence of strain, and to result in permanent disruption. There are three causes of such plasticity to be guarded against, within a stone subjected to great pressure: Cleavage and gliding-planes, sliding-surfaces, and the enclosure of lubricants.

(1) *Cleavage and Gliding-Planes in the Mineral-Grains.*— All the easily cleavable and frequently twinned minerals

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* Abstract published in *Stone*, 1898, and elsewhere. Reference has been made in the notes to the more important statements which have appeared in the literature of the subject, during the year since the reading of this paper, concerning points discussed herein.

—such as the feldspars, hornblende, calcite, dolomite, etc. —from this point of view, are possible sources of weakness in proportion to their abundance in any stone and to the readiness of their cleavage, distinctly shown in a dolomite-marble like that of Tuckahoe, N. Y. (*Fig. 17*). Especially in coarse marbles like this, the twinning or "gliding-planes" of calcite and dolomite mark the results of stress from ancient shearing, and are equal sources of dangerous motion under pressure; so, also, in the granites, with the twinning-which are the equivalent of the gliding-planes, in the triclinic feldspars.*

Were it not for the property of surface-adhesion in subsequent action, where this may be favored by the conditions, the plasticity and flexibility of marble would have found inevitable consequences, apparently, in rapid or immediate disintegration. Of that result we have evidence where surface-adhesion has been counteracted by weathering and infiltration, in the observed deep decay of granites, dolomites, marbles, etc., into loose sand. In the crushing of a non-homogeneous rock, such as granite, during subterranean movements, intermixture of fine particles or dust of a brittle mineral, like quartz, seems often to have interfered with continued cohesion of cleavage-planes of the other constituents, and so to have precipitated disintegration of the mass.

It has often been pointed out that the minerals of all others of the most facile cleavability, the micas, and especially the films of the soft and pliant hydromicas, whose

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*This is well illustrated in a description recently recorded in Maryland: "The rock from Texas is a very coarsely crystalline marble or 'alum stone,' in which the individual grains are sometimes ½ or ¾ of an inch in diameter. The constituents are weak in themselves, and they are weakly held together. The single grains show twinning striæ parallel to the crystal — ½ R that have been produced by a pressure, causing a gliding of the molecules over one another which has weakened the strength of the grain. Such a texture as is here shown renders the rock nearly worthless as a building-stone where small blocks must be used and great weights sustained. This is emphasized by the determination of the crushing strength, which is very low."—*E. B. Mathews*, *op. cit.*, 177.

flakes in some stones lie in parallel arrangement,* and in others irregularly disposed in all positions, appear to have been best adapted to promote internal motion and yielding of the grains of a stone under compression, in the same way as they act in quicksands. From their fissile texture, they have easily loosened into polished scales, which must have served under pressure as true a lubricant for motion of the surrounding grains as the scales of graphite on the pinions of an engine. In some rocks of slaty structure, "the laminæ are thrown into a series of small contortions in such a manner that the flakes of mica lie chiefly along certain definite parallel planes oblique to the general direction of stratification, which thus become planes of easy fracture or cleavage,"† and also, I think, of possible yielding and motion under heavy load, where, as in some parts of Europe, such rocks are used as building-stones. Probably the least objectionable form of mica, as affecting the rigidity and compressive strength of a stone, is that of shreds, strings and irregularly crumpled scales.

(2) *Sliding-surfaces* in rock structure. This term I would apply to the innumerable open fissures and clefts, often with smooth or even polished walls, which occur not only within but between the grains of stone, and which are found distributed through all rocks which have been subjected to great pressures during earth-movements. Along the axial lines of folding and crumpling of strata, geologist, miner and quarryman constantly meet on joint, fissure, fault, schist and bedding-planes, with the common and often beautiful display of *slickensides*. This old mining term is used to describe the highly polished and striated sheets and bosses where the jaws of the rock once ground together and oppos-

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* "It readily decomposes, and is an element of weakness, not alone from its disintegration, but likewise from the tendency of the flakes to lie all the same way and make planes of easy cleavage, along which the stone flakes and scales on exposure. The scaling is much worse where the mica is much decayed. It is one of the most injurious minerals that occur in sandstones."—Hopkins, *op. cit.*, 16.

† A. Harker, "On Slaty Cleavage and Allied Rock Structures," Rep. Brit. Ass. Adv. Sci. (1885), 837.

ing walls and seams rubbed and slipped over each other. Where the yielding was intermittent and the motion by jerks and starts, numerous miniature faults were produced throughout the mass, often shown by the faulted veinlets of calcite, invisible to the unassisted eye, in a thin section of limestone, though these may elsewhere be distinctly seen in a mere pebble picked up from the beach. Good illustrations of the larger forms of these have been thus described: "The polishing effects of the readjustments between the beds may often be seen in the slickensided surfaces of the major and stronger beds, and in cases of implicated folding the same phenomena are observable between the thinnest laminæ. A most striking instance of this polishing is seen in the Jura Mountains, where, at many places, both sides of the strong, thick layers of Jurassic limestone are polished as smoothly as if glaciated. They reflect the sun like an imperfect mirror. At some places where the folds are steep, layers have fallen down along these movement planes, exposing great surfaces of beautifully polished rock. In the folded Cambrian quartzites of Doe River, Tenn., the polishing of the layers by accommodation is scarcely less strikingly illustrated."*

But the view I now wish to press is that these well known macroscopic forms, familiar to the field geologist, must represent to but a small degree the enormous distribution of microscopic polished surfaces, plane, curved and irregular, intervening between the clefts and around the very grains in the interstices of stone. These interstitial slickensides may be assumed to abound especially in material in which the microscope reveals the presence of clefts and faults, and of grains (autoclastic) more or less rounded by mutual attrition during flowage, under compression. Microscopic faults, like those often shown in thin sections, presumably with slickensided surfaces, traverse the entire mass of many kinds of stone in the most complicated network, and have been connected with the development of joint-planes.† To one class of these minute dislocations Professor Heim* refers as fold-faults (falten-verwerfungen), in his discussion of his first type of cleavage, *strain-slip cleavage* (ausweichungsclivage), "that produced by a succession of displacements or minute faults, resulting from small contortions." As these polished surfaces usually lie in a multitude of planes variously inclined, the cohesion of many must be easily overcome by pressure in definite directions. Their consequent yielding and slipping must sometimes develop a grave source of weakness in building-stone; the resultant internal gliding, therefore, concerns the architect, engineer and builder as seriously, as it interests the geologist in studying the motion of strata, or the miner in searching for a lost lode. These glistening planes are familiar to every observer on the seams or folia of shales, slates and schists, where even the dissemination of sericite or other mica is commonly a proof and result of the sliding under compression. But the objection that the detection of the sheen on these minute surfaces must probably always remain beyond the reach of microscopical observation,† and that the above considerations are, therefore, in part presumptive, will hardly justify any further neglect of tests and precautions yet needed to guard against the danger of this concealed characteristic of the structure of stone. However, it must be

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* Van Hise, "Principles," etc., 600.

† "The study of many thousand divisional planes, which would certainly be regarded as joints by almost every geologist, has led me to the conclusion that

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the jointing and the faulting are concomitant. The faults are often extremely small, but it is very rarely that in a system of joint planes throws of an eighth of an inch or less cannot be detected; and where the rock is hard, slickensided surfaces will be found, even when the relative movement is much less than an eighth of an inch. Few geologists have been in the habit of looking for faults of such tiny dimensions, and I believe that the distinction between faults and joints has arisen from this omission. Partings due to tension would be free from slickensides."—G. F. Becker, *Bull. Geol. Soc. Am.*, IV (1893), 73.

* "Untersuchungen ueber den Mechanismus der Gebirgsbildung," Basel, (1878), II, 49–58.

† "The development of minerals along the crush-planes only takes place on an important scale in rocks originally crystalline, and even there, although the general effect is plain, the individual mineral constituents by which it is produced are for the most part extremely minute. It is a remarkable fact that, in a certain sense, a sheen surface is often more conspicuous to the naked eye than it is under the microscope."—T. G. Bonney, *Quart. Jour. Geol. Soc.* (1886), Proc., 107.

admitted, that, under those conditions in the subterranean metamorphism of rocks which have resulted in the closing of interstitial cavities (at a depth of 10,500 to 12,000 meters, according to Hoskins and Van Hise), the polished faces of these minute dislocations have become united and welded by molecular cohesion, in part or altogether, and their influence obliterated to that degree as surfaces of motion and weakness in the stone.

(3) *Lubricant.*—A strange disregard has hitherto prevailed, in my opinion, as to the influence of water on the internal mobility of stone. In the usual tests of the architect and engineer on compressive strength, the cubes used for the purpose have been scrupulously provided in a carefully air-dried state; apparently with the assumption that moistening or saturation would exert about the same effect upon the compressive resistance of stones of every kind. Yet, it is well known, the absorption-coefficient varies very widely, from a minimum in the dense stones, such as fine granites, up to that of porous cellular stones which absorb water like sponges, such as the poorer varieties of sandstones and limestones of loose texture.

Another needful coefficient, rarely distinguished, we may call that of absorption of moisture, the *moisture-coefficient*,* in distinction from that of saturation with water. The one indicates, as already suggested, the capacity of the seams and clefts, and merely the walls of the pores, to condense and hold watery vapor from an atmosphere saturated with moisture; the other, the *saturation-coefficient*, pertains to the entire capacity of the pores when filled with water; both are combined in the ordinary *absorption-coefficient*, in other words, the capacity, for saturation with water, of the entire interstices (the distinction of coefficients made elsewhere by me, in a study of the Syene granite,† referred merely to two methods and degrees of saturation of the pores). The moisture-coefficient differs widely, too, though not to the same extent as that of saturation, in the different kinds of stone.

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* N. H. Winchell, *op. cit.*, 185–186.

† "A Study of the N. Y. Obelisk," 158–161.

A familiar fact in common experience has been the decided softening and weakening of stone, under pressure, attrition or blows, while thoroughly soaked with water. It should be remembered that such softening may prevail continuously in a stone, even to the excessive degree produced by saturation, *e. g.*, from climate, as during a rainy season; from low or buried position, in foundations below the ground or the water-level; or even from permanent submersion beneath fresh or salt water, as in the foundations of a bridge, dock or pier. Notwithstanding these well known facts, few results of compression-tests have yet been recorded on cubes of stone, while in saturated condition by fresh or by salt water. But this universal constituent of stone, in the form of moisture, and common one, in the form of interstitial filling, in positions of saturation, serves in all cases, in proportion to its amount, as a lubricant of the other grains, promoting their motion and yielding under pressure and consequent weakening of the whole stone. One might as reasonably reject from consideration the micas in a granite or marble, as this permanent constituent of every stone, and always active lubricant, water.

We need to go back nearly a quarter of a century for the record of the few but most important experiments on this subject (*Revue de Geologie*, XIV, 1875–86), viz.:

CRUSHING WEIGHT (IN KILOGRAMS).

Kind of Rock.	Locality.	Size of Cube in C. Cm.	Wet.		Air-dried.		Stove-dried.		Authority.
			Range.	Average.	Range.	Average.	Range.	Average.	
Chalk	—	30	13·9–.6	18·6	16·5-35	23·5	80–92 5	86·2	Tournaire and Michelot.
Chalk	Issy.	5	—	12·9	—	23·6	—	36·4	Delesse.
Limestone . (Calcaire grossier)	Vitry.	5	—	26·9	—	52·8	—	76·	"
Limestone . (Calcaire grossier)	St. Denis.	5	—	21·8	—	31·2	—	48·7	"

The percentage losses of compressive resistance in the above four kinds of limestone, comparing the air-dried with the saturated cubes, are respectively: 20·85, 45·34, 49·05 and 30·13 per cent. A few more recent experiments have been published by F. Soule* (tabulated below), on two kinds of building-stone, from Calaveras County, Cal., in air-dried cubes, and in cubes saturated with water during seven or eight days. The influence of saturation of stone on its compressive resistance seems to rapidly increase in degree with the amount of absorption.

COMPRESSIVE RESISTANCE.

(In pounds, to the square inch.)

Building-Stone.	Locality.	Total Absorption (p. c. of weight.)	No. of Cubes.	Dry.	No. of Cubes.	Saturated.	Loss (per cent.)
Marble . . .	San Andreas, Cal.	0·30	4	3880	1	3730	3·87
Volcanic tufa	Santa Maria, Cal.	22·53	2	5435	2	2765	49·13

For the foundations of the New York and Brooklyn Bridge, the dense limestones from Kingston and Roundout, Catskill and Lake Champlain, were used, on account of the cheapness of the stone, its high specific gravity (2·69 to 2·75), and great crushing resistance (13,750 to 25,000 pounds to the square inch), the last property determined in the usual way on cubes of the stone in carefully air-dried condition. But who can now tell us the present crushing resistance of the blocks in that foundation, after their submersion in salt water for twenty years? Or that of more porous and absorbent stone, such as gneiss (*Fig. 7*), generally used throughout New York and Philadelphia in foundations of heavy buildings, of bridge-piers, etc., on the strength of results obtained on air-dried cubes? Or even that of the soft, porous and highly absorbent varieties of the imported "Carlisle stone," the freestones from Ballochmile, Gatelawbridge and Corsehill, Scotland (*Fig. 18*), in masonry com-

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**Stone*, XVI (1898), 433–434. Similar results, but with smaller differences, were obtained by Dr. Böhme, on testing sixty-four samples of limestone and fourteen of sandstone, in wet and dry cubes.—"The Strength of Quarry Stones," Am. Arch. (1882), 220.

monly seen in our streets, in contact with the soil, and so kept in permanently damp condition?

Again, petroleum and bitumen are frequent constituents, to a small extent, in sandstones and limestones, some of which have been brought into use as building-stones, such as certain sandstones of Ohio and limestones of Indiana with oily exudations. These also must act as lubricants of mineral-grains, but have been left out of consideration, in regard to their influence toward the strength of stone, in rejection of infiltrating water, or toward its weakness, in diminution of rigidity.

Besides the mica-plates, to whose influence as lubricants reference has already been made, graphite itself is commonly distributed in soft greasy flakes throughout limestones, gneisses and schists in Canada, on the southern border of the Adirondacks and elsewhere. Its presence would decidedly favor the internal flow of rock-grains under pressure, though such materials have as yet been rarely used in building. However, Vogt refers to its decided weakening influence on the compactness of certain marbles of Norway.

The general occurrence of such indications of weakness and yielding—cleavage, gliding-planes, sliding surfaces, and the presence of liquid lubricants—testifies to the conditions of instability and mobility which prevail in the structure of all building-stones.

Reference has already been made to anomalies constantly observed in the behavior, under stress, of stones of supposed uniformity in structure and homogeneity. Such have been, for example, remarkably abundant and strange during the usual crushing-trials of stone-cubes, even on those cut from the same block, of seemingly compact material, and carefully tested under the same conditions. In one, it may be at a low pressure, a crack suddenly appears, and the cube falls apart. Another becomes seamed by many fissures and splits into irregular fibers, flakes or lumps. Another explodes into gravel and powder, surrounding rudely pyramidal or conical forms. In another, the tensions seem to be more equably distributed, like those of the unstable molecules in unannealed glass, a

Prince Rupert drop, of which if you break but the tip, the whole bulb vanishes to powder. In such a cube, after long waiting, there comes at last a sudden report, and the mass of powerful stone shrinks in an instant to a handful of dust. This seems to be the ideal uniformity of internal conditions desirable within a stone, which thus ultimately meets the instantaneous fate which befell the far-famed "one-horse shay."

Yet from the four figures in this supposed experiment for resistance to compression, varying perhaps to *thousands of pounds*, obtained on these cubes (the differences on 2-inch cubes of the same stone, tested between wooden cushion-blocks, in Gillmore's experiments,* ranged from 6,000 to 15,000 pounds!), the average is ordinarily taken for the business report, and forms the basis, to the architect or engineer, for his "safety allowance," while the significance of the variations is disregarded and lost. There is evidently imperative need in such work of preliminary microscopical examinations of the internal structure of stone, and of chemical and physical tests of a special class, to thoroughly investigate the local minute tensions already existing and the defects of rigidity tending to flowage—those internal imperfections hitherto vaguely termed "flaws," "checks," "sand-cracks," etc., by experimenters—and to measure, if it be possible, the power of resistance of the stone to these; or, in other words, its coefficient of stability.

In this partial review of the characteristics of stone, with regard to mineral constitution and structure, in adaptation to its use as a building material, I have tried to call special attention to features whose importance appears partly neglected or entirely ignored. On their proper recognition, by exact methods of trial, must be founded the final selection of true and systematic methods for the series of tests for the correct treatment of different varieties of stone and for the best processes for its protection and preservation in our trying climate.

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* Gillmore, *ob. cit.*, pp. 28–31.

We may safely fancy that in the kingdom of Assyria, 6,000 years ago, the long-bearded architects of Asshur-banipal, as they stood planning the proper dimensions of alabaster-slabs for the wainscot in the palace at Koyunjik, relied largely on the Royal Rule of Thumb. This venerable rule is still extant, and bars the way to progress. An undue dependence upon so-called practical experience, with its limited glimpse of the internal nature of stone—a material whose most important structural characteristics are far beyond the reach of the unaided human eye—or, on the other hand, upon the present chaos of scientific methods and results of trial, unsystematic and uncorrelated, must inevitably prolong and increase the substitution of ashlar in thin veneering, of the petty mosaic of brick, of flimsy iron skeletons, and of pie-crust terra-cotta, in place of solid stone. But undoubtedly difficult as may be the thorough comprehension of the complicated structure and characteristics of this material and its skilful adaptation to present needs, these are well within the resources of modern investigation.

DISCUSSION.

T. C. HOPKINS, State College, Pa.:—Permit me first to express my pleasure and satisfaction in listening to Dr. Julien's remarks, which were certainly instructive and interesting to any one who has attempted to solve any of the many intricate and difficult problems connected with the durability of rocks, particularly in reference to those used for building purposes.

One of the important phases of this problem that needs further investigation is the action or influence of the quarry sap or quarry water. Its importance is realized by every intelligent quarryman, but a satisfactory explanation has not yet been given. It is a matter of surprise that the stone which comes from the quarry soft and friable, so soft at times that small pieces may be crushed to grains in the naked hand, should, after exposure for a few weeks, months or years, become so hard as to strike fire under the hammer; so hard, often, as to make it exceedingly difficult for the stonecutter to dress it to the desired form.

What causes this great change? The quarryman says the sun burns it hard, and he may not be far from right. What we want to know is the chemical or physical changes which take place in the stone. It must be more than the simple evaporation of water, and yet it seems hardly probable that it could be entirely from material held in chemical solution in the water. Is it not possible that sunlight and the atmosphere are more active on the commonly considered insoluble materials (such as quartz) than we think? How much of this indurating (might it not even be called metamorphic?) action is due to the physical or chemical action of the sunlight or how much to simple desiccation is a problem for investigation.

Another question of scientific interest is the source of the carbonic acid found so abundantly in the quartz of the granites. Is it all of organic origin? Can we consider it proof that the rock was formed from sediments from the lime and other carbonates or from organic material, or is carbonic acid a constituent of the original or first-formed igneous rocks?

Later, in reply to Dr. Day's remarks, Mr. Hopkins said that he thought that the hydrochloric acid test on granite would be of very little if any value in determining the comparative durability, as durability depends not on solubility in acids alone. It introduces an artificial condition to which the stone may never be subjected in nature, and while it will give the relative powers of the specimens to resist acid solutions, this may or may not be the ratio in which they will resist the atmosphere. It might even be an inverse ratio.

What would be more satisfactory, although more expensive would be to test the stones in the atmosphere itself. The results would not be immediately available, but it would be only a comparatively few years until useful results would be apparent, and in the course of time architects, builders and others would have data concerning our building-stone that would be invaluable; results that would also be of great value to scientists and serve as a check on any laboratory tests that might be used. Tests of this character would be properly in the line of government work, not only on account of its expense, but on account of its long continuance, the impersonality of the results, and the better facilities both for performing the tests and distributing the results.

Stated Meeting, March 9, 1899.

THE IRON ORES OF THE OURAL MOUNTAINS, RUSSIA.

BY H. B. C. NITZE.

At a time when the Russian Government is assuming a more liberal and progressive policy for the development of its home industries, and is giving encouragement to the investment of foreign capital, it may be of interest to say something of the iron-ore resources of this rich and vast territory.

I shall confine my remarks to the Oural Mountain region, the cradle of the Russian iron industry, which was founded by Peter the Great over two centuries ago. The growth of this industry has been extremely slow, owing chiefly to the great inaccessibility of the region; and for this reason, too, the mining and metallurgical methods have progressed but little towards the present high state of modern practice.

But, with the extension of various important railroad connections, at present either completed, in course of construction, or definitely proposed, a progressive development of the Oural iron industry may confidently be expected.

The region under consideration may be divided into the northern, central and southern Ourals.

The northern Oural district is the least developed. Some small deposits on the western slopes produce 45 to 50 per cent. ores. Further in the interior of the mountain chain are large ore-bodies, such as the Kutinski and the Jubrischski mines, which produce rich specular ores, containing 60 to 65 per cent. metallic iron, at a cost of 65 cents a ton at

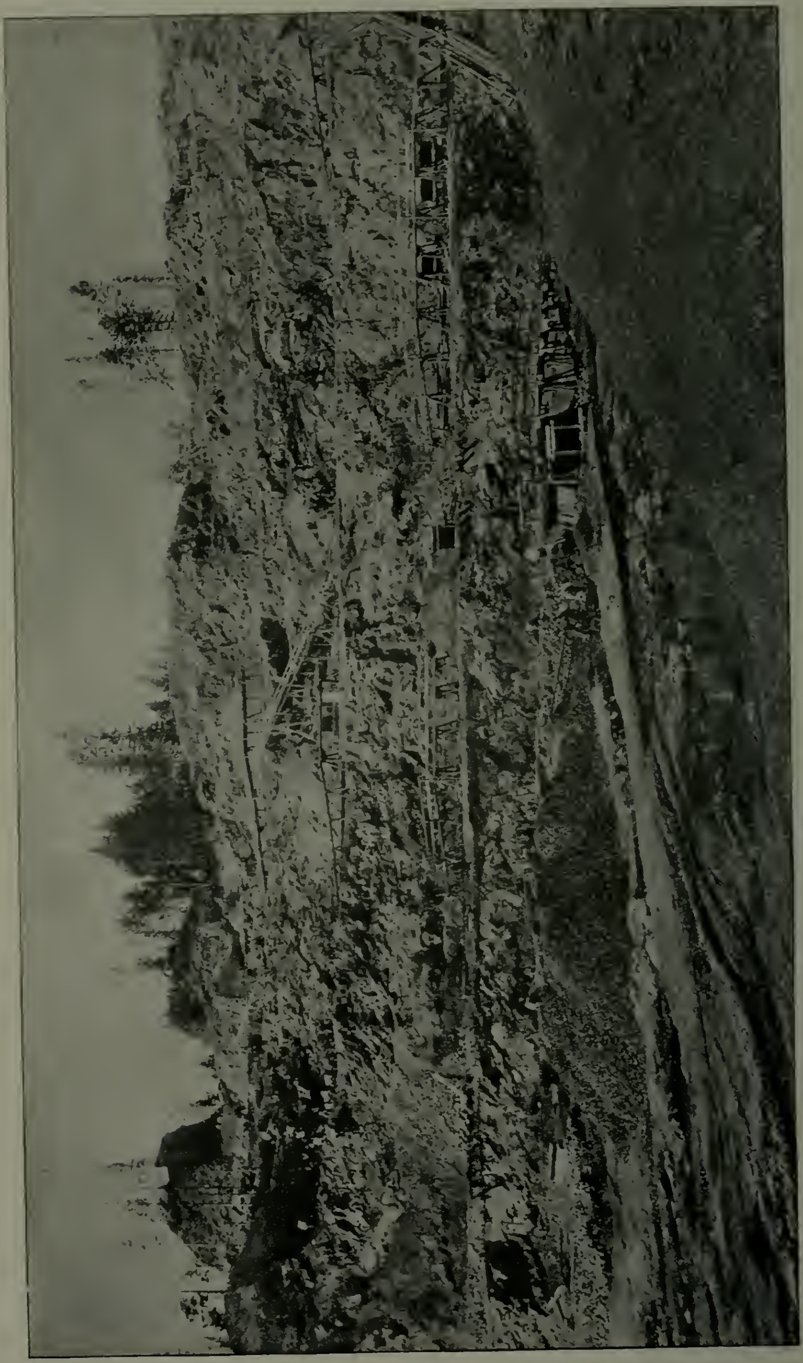

FIG. 2.—Workings of the Blagodat mines.

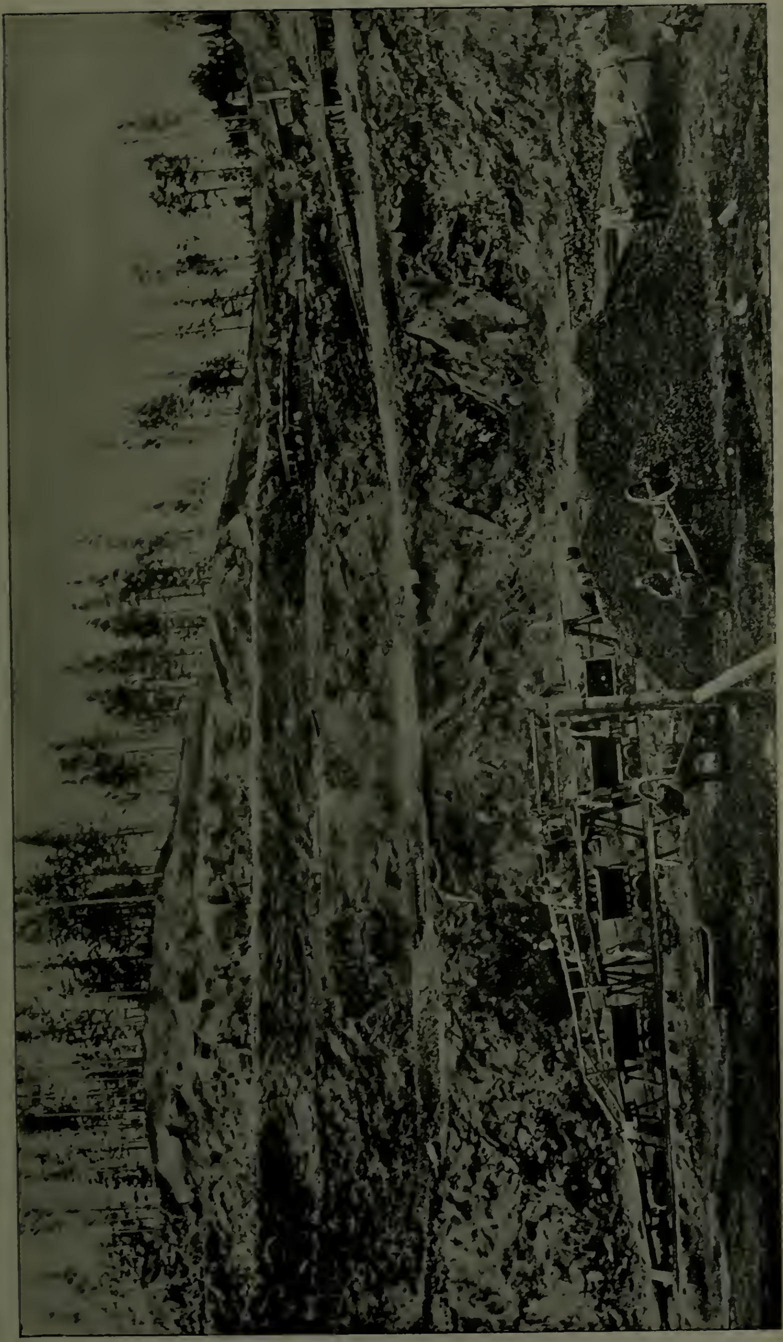

FIG. 3.—Workings of the Blagodat mines.

the mines. The district of Bogoslovsk produces 50 to 60 per cent. ores, worth 90 cents at the mines.

The ore-deposits of the middle or central Ourals are more developed, and are concentrated within a smaller area. The two principal producers are the Blagodat mines at Kouchwa, and the Wyssokaja mines at Tagil, both on the line of the Perm-Ekatherineburg railroad.

The Blagodat mines, property of the Crown, are situated on the western slope of Mount Blagodat, an isolated peak, which rises to a height of about 500 feet above the surrounding country, and 1,150 feet above the sea-level. The summit of this mountain is occupied by a Greek chapel, erected as a monument to Stepan Tchoumpin, who, according to tradition, was the discoverer of the ore-deposits.

The predominating rocks are porphyries, which show all phases of transition, from coarse-grained augitic syenites to perfectly compact orthoclase rocks. They lie in contact with Devonian strata which have been largely altered to garnet-epidote rocks, the result of contact metamorphism. The ore is magnetite. Attention is directed to the structure of the ore-deposits and the enclosing rocks (see *Fig. 1*). There is a more or less distinct arrangement in parallel beds, folded into an anticlinal or saddle near the crest of the mountain, one member dipping westward with the slope of the mountain at an angle of 40° to 40°. The regularity of this structure is affected by two series of faults, the one extending north and south, and the other nearly east and west. Owing to the throws of these faults the original position of the beds is often considerably disturbed. The ore-bodies contain some feldspar, and at the boundaries of the beds they pass gradually into the composition of the porphyry. They may be looked upon as magmatic differentiations in the porphyry mass. The mines are in the shape of immense, terraced open cuts (see *Figs. 2* and *3*).

The ores average 60 to 65 per cent. metallic iron, and are very free from deleterious ingredients. The cost of the ore at the mines is $1.27 per metric ton. The annual output is about 7,000 metric tons, consumed exclusively by the government iron works.

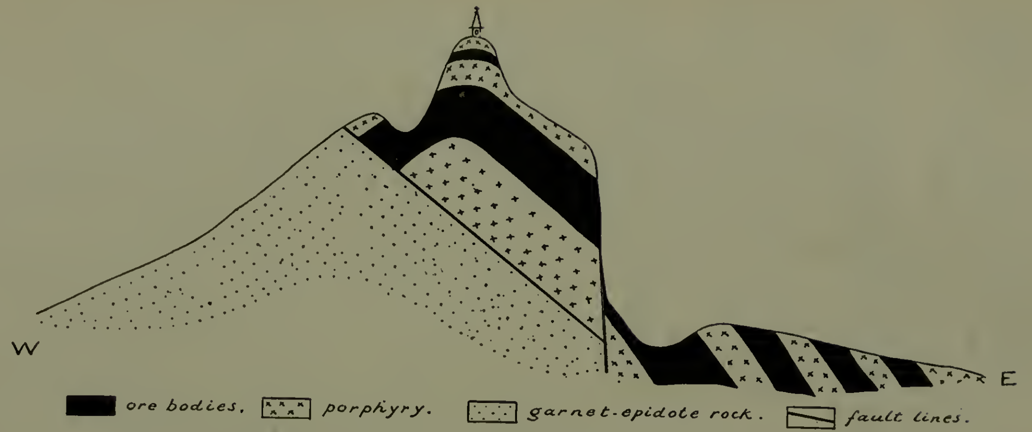

FIG 1.—Showing relation of ore bodies and country rock at the Blagodat mines.

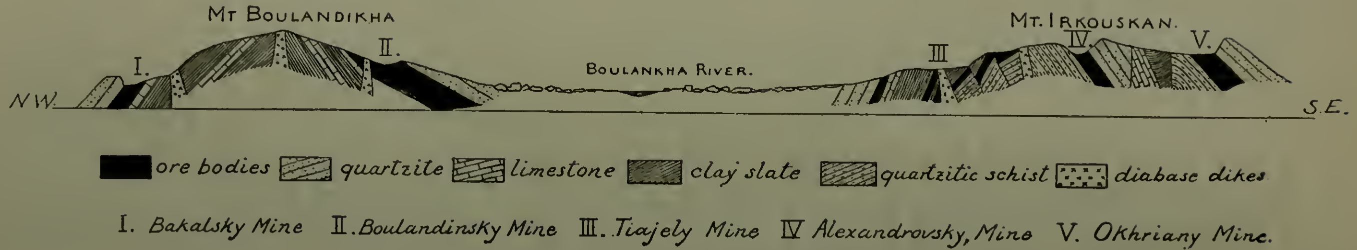

FIG. 5.—Geological section at the Bakalski mines.

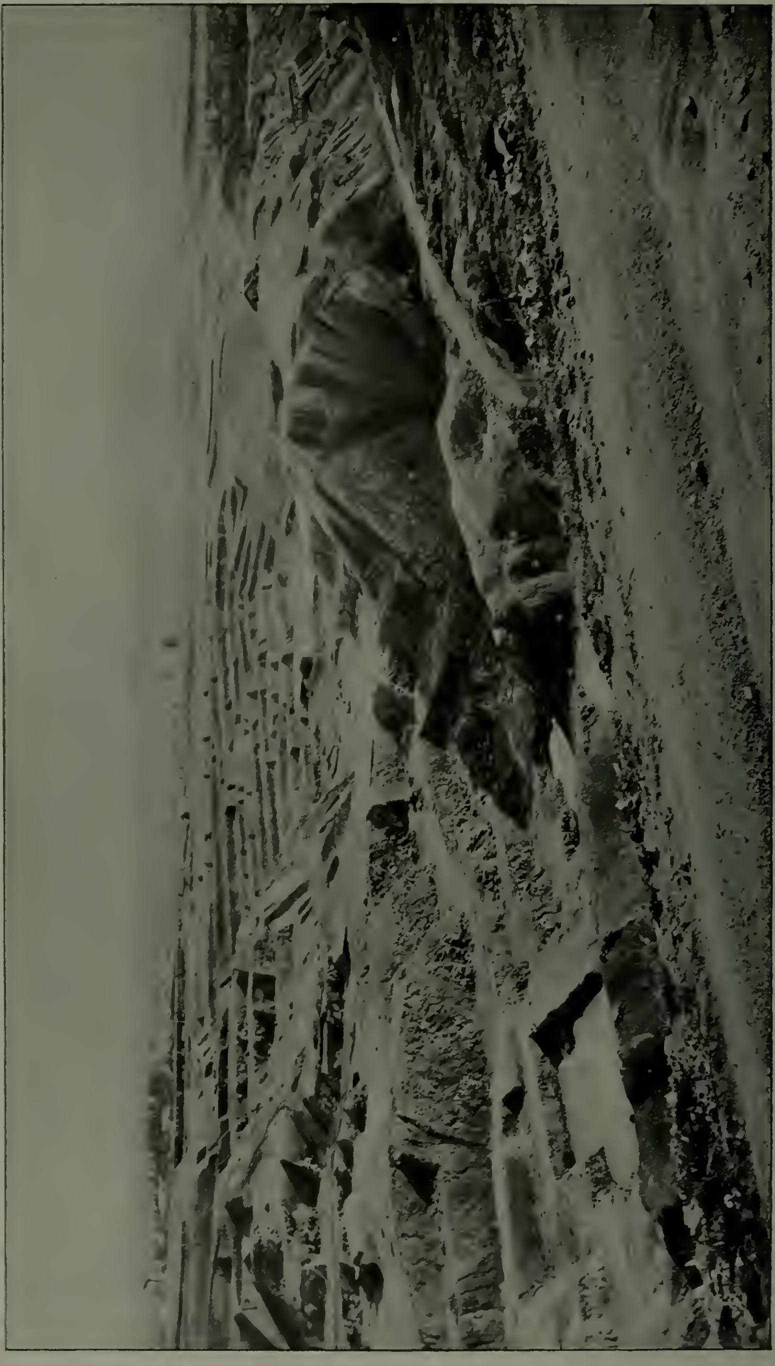

FIG. 4.—Workings of the Wyssokaja mines at Tagil.

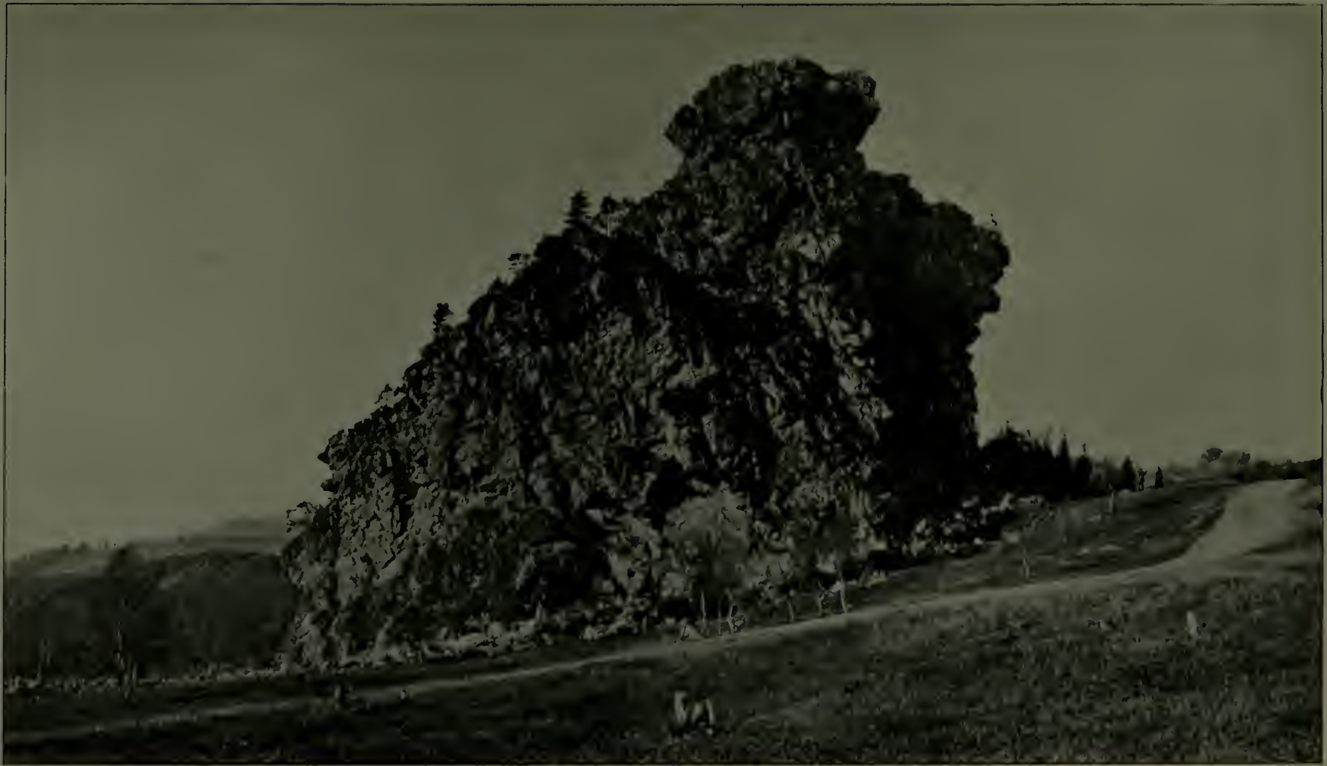

FIG. 6.—Quartzite outcrop at the Bakalski mines.

The Wyssokaja mines are situated on Mount Wyssokaja (High Mountain), at Nijne-Tagil, about 30 miles south of Kouchwa. They are the property of the heirs of P. Demidow, prince of San Donato. The character and structure of the ore-deposits and associated rocks, as well as other conditions, are in all respects similar to those of Blagodat. *Fig. 4* shows a view of a part of the Wyssokaja mines. The annual output is 20,000 metric tons, which supplies the neighboring iron works of Nijne-Tagil, Niewiansk, Alapaievsk, Werkhissetsk, Soukhsounsk and Revdinsk.

The southern Ourals are the richest in ores. The two principal localities are the Bakalski mines, in the district of Slatoust, and the Magnetnaia mines, in the region of the Oural Cossacks.

The Bakalski mines are situated at the terminus of a branch railroad, completed during the summer of 1898, from the station Berdiansk on the Trans-Siberian railroad. The country is traversed by three principal ore-bearing mountain ranges, the Chouida, the Irkouskan and the Boulandikha, which are composed of Lower Devonian strata in the following order of geological succession (see *Fig. 5*):

(*a*) Quartzites and sandstones, constituting the crests, and standing out in fantastic relief (see *Fig. 6*).

(*b*) Diversely colored schists enclosing subordinate beds of gray dolomitic limestone.

(*c*) Quartzitic, sericitic and argillaceous schists, with black and gray dolomites.

These rocks are intersected by highly altered diabase in the form of intrusive dikes, bosses and sheets. The orebodies (limonite and spathic ore) occur as beds, reaching a thickness of as much as 130 feet, in the horizon (*b*), and are intimately related to the dolomitic limestones, the gradual transition of limestone to spathic ore and limonite being clearly visible. The anticlinal structure, particularly of Mt. Irkouskan, is broken by a series of faults, extending in a northeast and southwest direction with the course of the mountains.

The mines of the district fall under three ownerships:

(1) those operated by the Crown, supplying the Satkinsk and Slatoust works; (2) those operated by Mr. Balachew, supplying the Simsk and Nikolaiewsk works; and (3) those operated by Prince Bieloselsky-Bielosersky, supplying the Kataw and Jourezan works. The total annual output of these mines is 100,000 metric tons of ore, containing up to 60 per cent. metallic iron. The cost of mining, which is carried on entirely in open-cuts, is 58 to 66 cents per ton.

The Magnetnaia mine is situated on a mountain of the same name on the left bank of the Oural River in the country of the Cossack steppes. It is leased by the Bieloretzki iron works, and has an annual output of 50,000 metric tons of high-grade magnetite ore, costing something like 50 cents per ton at the mine.

There are a number of smaller mines in the southern Ourals, furnishing a total annual output of about 100,000 metric tons. Among these are the Awzianski and the Inersk mines, producing 50 to 60 per cent. ores at a cost of 72 cents per ton.

The total production of pig-iron in European and Asiatic Russia for the year 1897 was 1,835,540 metric tons, of which 723,500 tons were from South Russia and 676,000 tons from the Oural region.

Some few of the Oural mines are fitted with modern mechanical appliances, as the Auerbach mine in the Bogoslovsk district, but the vast majority are operated entirely by hand labor and horse-power, in the most primitive manner. When not occupied in the field, the peasant works in the mine, usually on the tribute system. This class of labor is cheap, but uncertain, and the work is spasmodic and ruinous to the future development of the mines. The hauling is usually done by women and children in veritable toy carts holding about 500 pounds. The blast furnaces are of antiquated types, having a capacity usually of not over 30 to 50 tons. The fuel is, without exception, charcoal.

The evident lack of progress in the development of the iron mining and metallurgical industry must be attributed largely to the dearth of transportation facilities. The iron ores of the Ourals are of excellent quality, and the resources are abundant. It will be necessary, among other things, to connect these ore supplies with the Donetz coal basin of South Russia, and steps in this direction have already been crowned with partial success.

A STUDY OF THE MICRO-STRUCTURE OF BRONZES.

BY E. HEYN,

Engineer in Charge of the Micro-Metallurgical Department of the Royal Prussian Testing Bureau at Charlottenburg. Translated for the *Journal* by PAUL KREUZPOINTNER, Testing Department Pennsylvania Railroad, Altoona, Pa. To which are appended remarks by the Translator, A. E. OUTERBRIDGE, JR., and ALBERT SAUVEUR.

MR. HEYN:—In Vol. CXLVII, No. 1, of the *Journal of the Franklin Institute*, a very stimulating lecture is published on the micro-structure of bronzes.

The lecture was delivered by Mr. Outerbridge. The address, as well as the discussion following, are proof of a very lively interest on the subject of metallography by prominent American specialists.

However, it is our experience that frequently the original enthusiasm with which a subject was taken up meets with the discouragement of real or imaginary disappointments while pursuing the subject under investigation. Such a reaction is dangerous to the cause, having a tendency to prevent progress or at least make progress more difficult.

Mr. Clamer summarized the points of the lecture and discussion in the following sentences:

"Structure is not only affected by the temperature of pouring, rate of cooling, or, in other words, heat treatment, but also by the size of casting and method and time of etching, etc., and for this reason I agree with Mr. Outerbridge in his statements regarding the necessity of standard methods."

In the foregoing, I wish to lay particular stress on the point where Mr. Clamer says: "Structure is affected by method and time of etching," because this point is the one where, under unfavorable circumstances, the above-mentioned reaction may be produced. To prevent this is my desire.

The micro-structure of a metal, in whatever condition of temperature or mechanical treatment is peculiar to that condition, and remains unalterably at that condition precisely as the other properties of a metal, like strength, hardness, specific weight, etc., are peculiar to a given temperature or stage of mechanical treatment of a metal.

Hence, it is impossible to conceive the micro-structure itself to be changed by the time of etching.

Recognizing this as the foundation upon which to build all metallographic work, I am in entire accord with the views of most metallographists, particularly with those of my teacher in this line of work, Prof. A. Martens, who most kindly permitted me to assist him in the continuation of his work.

It is true that, under certain circumstances, we may receive a varying impression of the micro-structure according to the manner and form such micro-structure is presented to our vision. According to one method we make the structure visible by showing the difference in hardness by means of the so-called "relief-polishing." According to other methods we try to obtain a knowledge of the differences in structure by the peculiarity of different portions of a specimen which have been colored differently by an etching fluid; or we make use of the fact that some portions of a structure are attacked more readily by a given acid than others. One and the same part of a structure may assume a different color according to the kind of etching fluid used.

However, all the various impressions, produced by various means must lead us, with due regard to all accompanying circumstances, to a proper observation of the characteristics peculiar to a given micro-structure. Using different means, the observer is able to acquire a knowledge of the various properties peculiar to the different elements of which the structure of a metal is composed, thus enabling him to get a general view of the micro-structure as a whole.

Fig. 1.

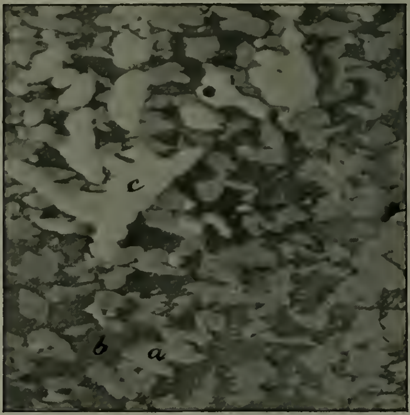

Fig. 2.

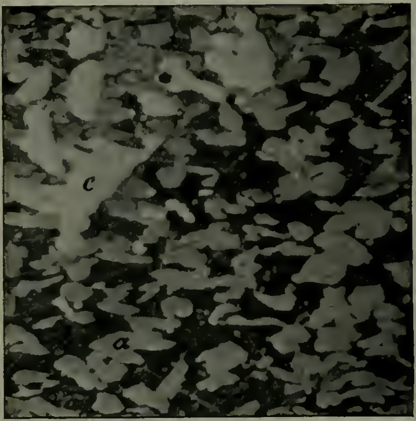

Fig. 3.

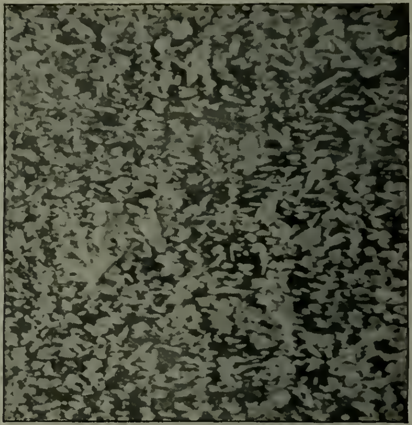

Fig. 4.

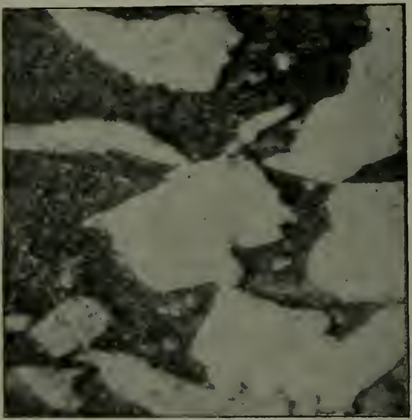

Fig. 5.

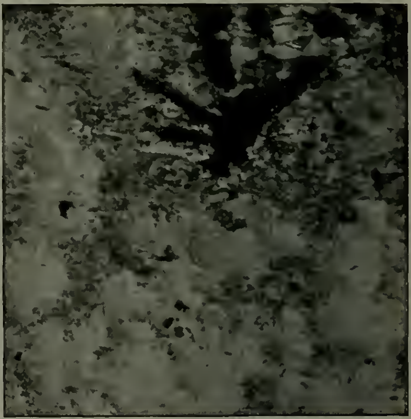

Fig. 6.

It is obvious that the latter object will be attained the more completely the more the peculiarities of a structure have been revealed by the use of various methods. It is not always an easy matter, though, to arrange the details obtained into a harmonious whole, especially since the observer may be misled by unusual features in the structure.

The main aim of scientific metallography at present must be to study in all their ramifications the varying phenomena observable when using divers metallographic methods. The phenomena thus observed must be sufficiently well defined to exclude all possible deceptive features.

Whenever metallography has solved this problem, then the way is open to propose such methods as may be applicable to specific cases, and to simplify such methods in a manner so that non-experts may be able to draw conclusions with tolerable certainty.

At present it would seem as if the establishment of standard methods would, in many cases, tend to misunderstandings.

In order to contribute something towards the final attainment of the aim described above, attention is called to some features of micrographic work which have come under my observation more or less frequently.

I hope not to be considered an intruder if I take the liberty to present some results of an examination of machinery bronze, made at the Royal Mech.-Technical Testing Bureau at Charlottenburg, and which may be considered a supplement to the paper read by Mr. Outerbridge.

I regret not to have been able to obtain the analyses of the bronze.

Figs. 1 to *8* of the photographs present features strongly indicating similar characteristics of the structure of this bronze, notwithstanding its treatment with a variety of methods.

The material experimented with was a piece of metal which had been used for a crushing test, the section to be examined being a face perpendicular to the one under compression.

Fig. 1 gives the structure after polishing the piece upon cloth with Parisian-red. Many bluish-white segregations, *c*, are visible in a somewhat depressed yellow matrix. In the latter the micro-structure is but faintly marked. After five minutes' etching in diluted sal-ammoniac the structure *Fig. 2* was obtained. *c* remains unchanged. In the vicinity of *c* (probably so-called tin-spots) yellow, angular crystals, *a*, are imbedded in a reddish-brown matrix, *b*. Etching fifteen minutes more with the same fluid no change takes place, except a more marked difference in the colors. This is seen in *Fig. 3* as compared to *Figs. 1* and *2*, and less magnified in *Fig. 4*.

Matrix *b* shows, under increased magnification, in *Fig. 5*, marks of a eutectic alloy.

After this the test-piece was relief-polished upon rubber with Parisian-red and water and etched for twenty-eight minutes in a solution of 1 part nitric acid, 1 part muriatic acid, and 18 parts water.

This produced the structure *Fig. 6*. The parts *c* are colored black and surrounded by a bluish halo. The impression is created as if the structure had been completely changed. However, this is an illusion and one of the sources of trouble the metallographist has to deal with. When the object was examined under a blue light (by holding a blue glass between the light and the prism), then *Fig. 7* was obtained, in which the original structure *a* and *b* can be recognized; its appearance was made considerably more definite when. instead of the blue glass, the Zettnow filter (light filter) was used, consisting of 160 grains nitrate of copper, 14 grams chromic acid, 250 grams water, throwing waves of light of a definite length upon the object, producing *Fig. 8*.

Therefore, we see that form and position of the details of the structure remained the same, only the colors changed; *a*, has become reddish with a bluish hue, containing numerous round, blue specks, increasing in numbers towards the center of the piece; *b*, is pure red. It is possible the accumulation of the blue specks in *a*, towards the center may be due to a changed chemical composition from the circumference towards the center of the piece, as was found by Charpy when using other methods.*

Even after etching the specimen in nitro-muriatic acid (aqua regia) for eighteen hours, no change had taken place in the formation of the structure *a* and *b*, except *b* having been eaten into a little deeper than *a* by the acid.

No change was likewise produced by immersion of the specimen in a solution of blue vitriol for twenty-three minutes and passing through it a current of electricity. For chemical reasons I abstained from etching this bronze with strong nitric acid.

On dissolving copper-tin bronze in nitric acid the tin is precipitated as stannic oxide, in the form of a white sediment. I was afraid this would happen when etching with strong nitric acid, causing a thin film of this white tin-sediment to be deposited partly upon the surface of the specimen, thus covering the view of the structure. How far in this respect my anxiety would have been justified I have not proved thus far by actual experiment.

There is one thing which, under certain circumstances, may cause the erroneous conception that the structure was changed by the etching.

Let us suppose the specimen to have been cut at right angles to the etched surface. If now the structure was brought out by any method, on that section of the metal it would present itself as in *Fig. 20*, revealing the depth of the etching to the line *a—b* on the originally etched surface, done by means of a strong etching fluid. We see at once the apparent change that has taken place in the structure. Such change becomes more noticeable the deeper the etching and the finer the structure. I would also call attention to a third phenomenon which shows itself especially with steel, containing ferrite, and which, likewise, easily leads to the erroneous impression as if etching would change the structure. If we etch a crystal, for instance of calcite, in muriatic acid, its surfaces will not be attacked uniformly.

**Bulletin Soc. d'Encour. p. l'Ind. Nal.*, March, 1897. *Metallographist*, 1898, Vol. I, Nos. 2 and 3, p. 196.

Regular depressions will appear, intimately connected with the symmetrical system of the crystal. These depressions are known to the mineralogist as "etch figures."

Even if the crystal is cut into sections in various directions, these etch figures are obtained. They are uniform on faces which are uniform from a crystallographic point of view, and they are variable if the faces vary from a crystallographic standpoint.

Under certain circumstances these etch figures are so closely arranged as to make the surface appear to be composed of small crystals.*

The etch figures may even become such a compact mass that the surface appears dark under a low power, and not until a high power is used will their true nature be revealed. If, for instance, crystals of calcite are thrown together without semblance and order, as is the case in marble, then a cut through the mass will bisect the crystals in all possible angles.

According, therefore, to the angular position of the etch figures, some of the individual grains of calcite will appear quite dark, while others remain light with low magnification, not only with the light falling at an angle, but also if it falls vertically through the prism.

We likewise observe these etch figures and their compact arrangement with the ferrite grains of steel, because they are crystals which were more or less hindered in their development by close contact to their neighbors.

In this case the etching must be continued with strong acid for some time.

Under a low power, certain grains therefore also appear quite dark, or even black, so as to make their mistaking for perlite possible when but superficially examined.

Only after the highest possible magnification is the true character of the structure revealed. This phenomenon is certainly of importance in connection with the question under discussion. To enter more fully into details would

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*Stead, "The Crystalline Structure of Iron and Steel," Iron and Steel Institute, May meeting, 1898.—*Metallographist*, Vol. I, No. 4, 1898

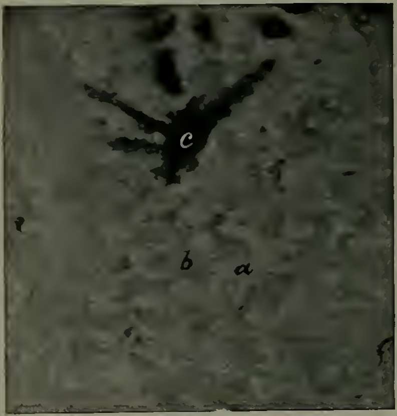

Fig. 7.

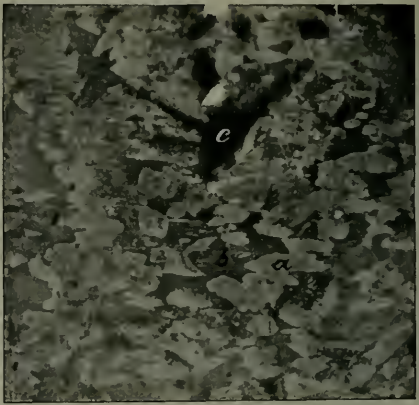

Fig. 8.

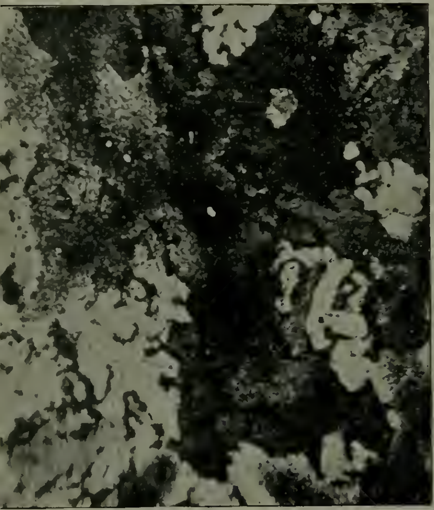

Fig. 9.

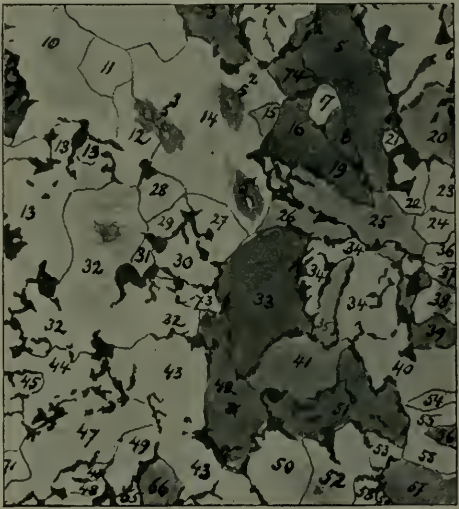

Fig. 10.

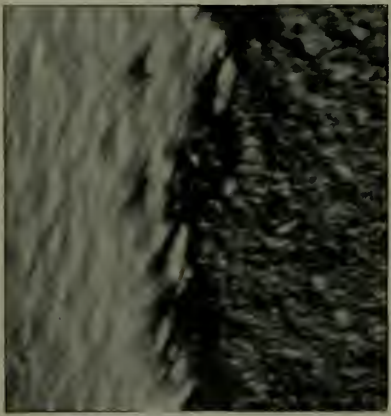

Fig. 11.

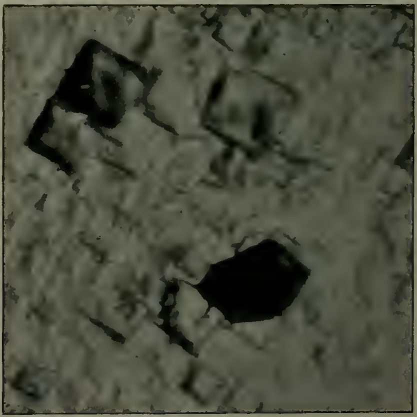

Fig. 12.

take us too far out of the way. I discussed this subject very thoroughly in Heft VI, 1898, of the Mittheilungen of the Royal Technical Testing Bureau in Berlin, under "Untersuchungen auf tiefgeätzten Eisenschliffen." (Investigations on deeply etched specimens of steel.—Flusseisen.)

For better explanation I added a few photographs which refer to an ingot of soft Thomas flusseisen.

Fig. 9 shows a portion of the same, 123 times magnified, etched for six minutes in double chloride of copper and ammonium in proportions of 1 : 12. There are large dark blotches; others are white, while the lines of demarcation between them are not sharply defined.

On etching more strongly these blotches seem to change their position partly. If, however, these blotches are examined under a high power, there may be noticed minute segregations of perlite within the main body of ferrite. The latter appears to be resolved into individual grains (crystals) of different degrees of lightness. *Fig. 10* is a hand-drawing of *Fig. 9* for a better understanding of the matter. The perlite is shown in black, while the crystals of ferrite are numbered and shown in lighter or darker shades, according to their degree of lightness. The line of demarcation between the light crystal, No. 43, and the dark ferrite crystal, No. 42, is 1,650 times magnified in *Fig. 11*.

In this figure we can plainly perceive the reasons for the different shading. It is due to the varying angular position of the neighboring crystals to the axis of the microscope. In one and the same crystal no difference of position or form will be perceptible in the etch figures, but there is a difference as to the depth they are eaten into by the acid. Especially in the neighborhood of minute slag spots the crystals are eaten into more deeply than elsewhere. Under a low power the crystal appears darker at such spots, as shown in *Fig. 12*, under a 1,650 magnification, which illustrates a portion of the dark spot in crystal No. 32.

This phenomenon has been at present followed up only in specimens of steel (flusseisen), but will be found in all metals whenever the structure has assumed the form of crystals. There is another, a fourth, circumstance which may occasionally create the impression as if a change of structure was owing to the time and method of etching. This is due to photographic reproduction.

Micro-photographing is by no means such a matter-of-course operation as it is often thought to be, but depends in its results very much on the skill and understanding of the operator. How seemingly different a structure may appear, according to the manner it has been photographed, is shown in *Figs. 13* to *16*. As a test piece rail steel was used. The specimen was taken from the web and was etched for one minute in double chloride of copper and ammonium of 1 : 12 strength. *Fig. 13* was taken with the objective 35 of Carl Zeiss in Jena with a magnification of 29 diameters, and using a prism above the objective for the purpose of better light. The structure is reproduced excellently.

Fig. 14 is a photograph of the same spot with the same magnification, the vertical light being obtained by means of a "plane parallel glass" 0·5 millimeter thick, and which was inserted between the object and the objective at an angle of 45°. Under that light the structure appears somewhat different, while under a reduced light brownish and dark hues on the photographic plate produced the same results.

A more serious error is illustrated in *Figs. 15* and *16*, fifty times magnified, with the use again of the "plane parallel glass." In *Fig. 16* this was only 0.2 millimeter thick, but when photographing No. 15 the thickness of the glass was 0.5 millimeter. With *Fig. 15*, *a* and *b*, an experiment was made by having the objective at different distances from the object.

Both *a* and *b* are reproductions from the left half of *Fig. 16*. However, the structure in *Fig. 15*, *a* and *b*, is distorted to such an extent as not to resemble the real structure of *Fig. 16*.

Many similar examples could be given. Concerning this matter I beg to call attention to a description of "Die Mikrophotographie im auffallenden Licht und die mikrophotographische Einrichtung der köngl. mechan. tech. Versuchsanstalt in Charlottenburg, von Prof. A. Martens und Ingenieur E. Heyn."

Improper etching may also cause mischief occasionally. Thus, for instance, *Figs. 17* and *18* are nearly full-size photographs of transverse sections of a round bar, turned from the head of a "Thomas" steel rail.

Fig. 17 was etched in a 2 per cent. solution of nitric acid for twenty-four hours. *Fig. 18* was etched for five minutes in double chloride of copper and ammonium of 1:12 strength. The difference in appearance may thus be explained. See *Fig. 21.*

Upon the surface of the test piece the fluid becomes saturated with salts of iron, and this saturated solution will have less and less effect on the specimen to the degree that saturation proceeds.

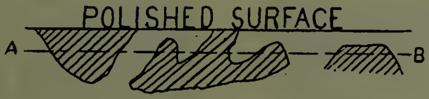

FIG. 20.

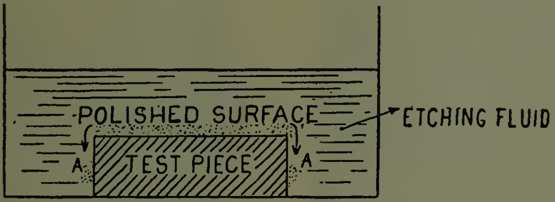

FIG. 21.

On the sides, however, the saturated solution will descend, as indicated by the arrows *a a* to make room for fresh fluid. As a consequence the sides and edges of the specimen are etched more effectively than the middle, as shown in *Fig. 17*. This is not noticeable in *Fig. 18*, which was etched only 5 minutes and the specimen was continually moved about in the fluid during that time.

To confirm this partial effect on the specimen more completely, a test piece, taken from a flat bar of dead, soft basic open-hearth steel, as in *Fig. 19*, was etched for three minutes in double chloride of copper and ammonium 1:12, without giving any motion to the fluid. The more effective action of the fluid along the edges is plainly visible. It is easy to see how erroneous conclusions may be drawn, due to such appearances, as if there were segregations present.

Whenever segregations are suspected, then the only reliable way to proceed is, if the etching is to be of any value, to repeatedly grind and polish and etch the specimen with different etching fluids, using all possible precautions to see whether the same effect is produced each time.

In the paper read by Mr. Outerbridge, the desirability was expressed of a standard-sized specimen for etching.

Concerning the size of a specimen, this is a matter of convenience or necessity, according to the needs of the occasion, or the amount of material on hand.

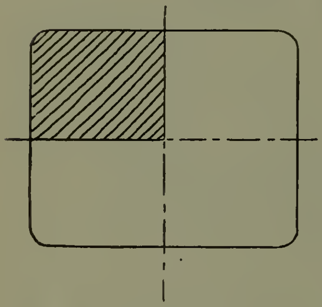

FIG. 22.

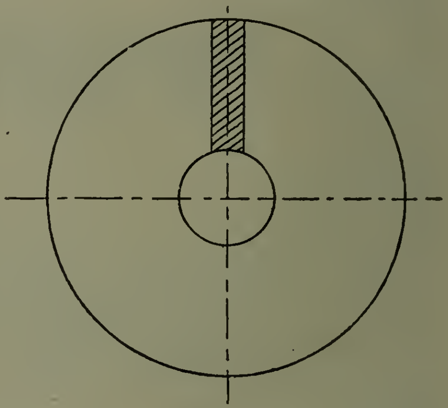

FIG. 23.

In the laboratory at Charlottenburg, it is the rule to obtain, if possible, a complete cross-section of the object to be examined, be that a bar, beam, rail, etc. If the object to be examined is very large, or bulky, like an ingot or heavy forging, a piece is cut out which, apparently, includes the portion of the structure to be examined.

Fig. 22, for instance, shows a specimen cut from an ingot, and *Fig. 23* one from a heavy shaft.

The work is controlled and checked by preparing other similar specimens which are expected to give similar results.

Of course, in order to examine with the microscope and

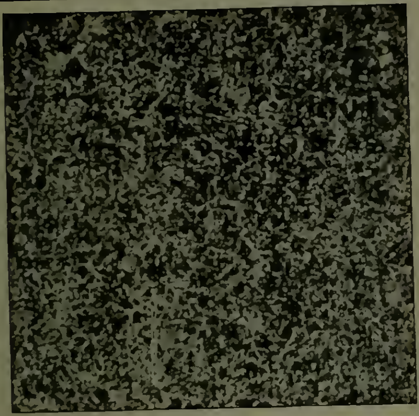

Fig. 13.

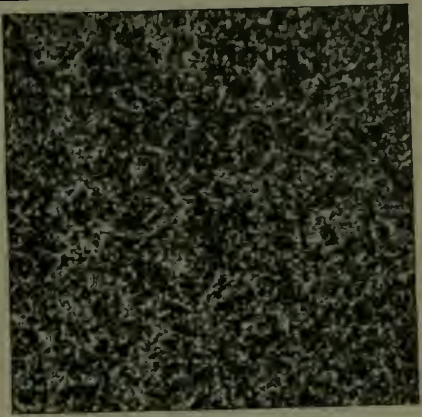

Fig. 14.

Fig. 15a.

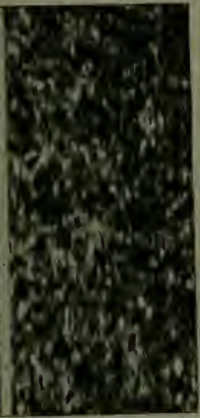

Fig. 15b.

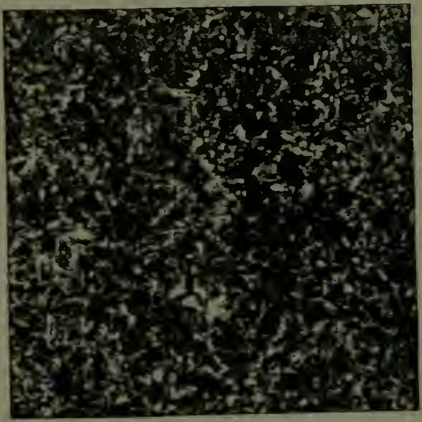

Fig. 16.

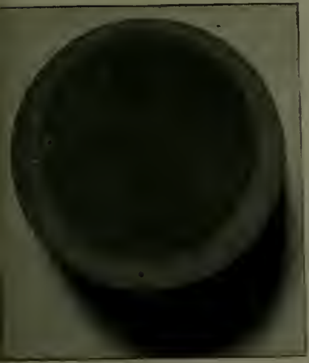

Fig. 17.

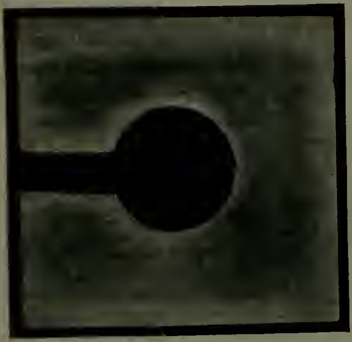

Fig. 19.

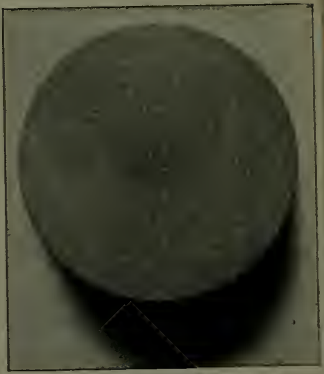

Fig. 18.

EVYTYPE CO., ENGRAVERS AND PRINTERS, PHILADELPHIA.

to photograph specimens of large dimensions and comparatively heavy weight, it is necessary to be provided with a properly arranged stand, such as is found with the micro-photographic apparatus of Marten's design. Should only a detail-examination of the structure be desired, then smaller specimens of convenient size answer the purpose as well.

CHARLOTTENBURG, GERMANY, March 5, 1899.

DESCRIPTION OF PHOTOGRAPHS.

FIG. 1.—Magnification, 365 diameters. Vertical light through prism. Machinery bronze. Polished on cloth.

FIG. 2.—Magnification, 365 diameters. Machinery bronze. Polished on cloth. Etched five minutes in sal-ammoniac.

FIG. 3.—Magnification, 365 diameters. Vertical light through prism. Machinery bronze. Polished on cloth. Etched five minutes in sal-ammoniac. Etched fifteen minutes more in sal-ammoniac.

FIG. 4.—Magnification, 123 diameters. Vertical light through prism. Machinery bronze. Treatment same as FIG. 3.

FIG. 5.—Magnification, 1,650 diameters. Vertical light through prism. Machinery bronze. Details of FIG. 3.

FIG. 6.—Magnification, 365 diameters. Vertical light through prism. Machinery bronze. (1) Polished on cloth. (2) Etched five minutes in sal-ammoniac. (3) Etched fifteen minutes more in sal-ammoniac. (4) The relief polished on rubber, with jeweller's rouge. (5) Etched twenty-eight minutes in 1 part nitric acid; 1 part muriatic acid; 18 parts water.

FIG. 7.—Magnification, 365 diameters. Vertical light through prism. Photographed through blue screen. Subject, same as FIG. 6.

FIG. 8.—Magnification, 365 diameters. Vertical light through prism. Taken with Zettnow filter. Subject, same as FIGS. 6 and 7.

FIG. 9.—Magnification, 123 diameters. Vertical light through prism. Block of soft "Thomas" cast steel. Etched six minutes in double chloride of copper and ammonium, 1 : 12.

FIG. 10.—Magnification, 123 diameters. Sketch by E. Heyn, giving key to FIG. 9. Perlite, black; ferrite, white to gray.

FIG. 11.—Magnification, 1,650 diameters. Vertical light through prism. Compare with FIGS. 9 and 10. Line of demarcation between the light ferrite grain, 43, and the darker ferrite grain, 42.

FIG. 12.—Magnification, 1,650 diameters. Vertical light through prism. Compare with FIGS. 9 and 10. The dark spot occurs in ferrite grain, 32.

FIG. 13.—Magnification, 29 diameters. Objective, 35. Vertical light through prism. Rail steel. Etched one minute in double chloride of copper and ammonium, 1 : 12.

FIG. 14.—Magnification, 29 diameters. Objective, 35. Vertical light

through plane glass of 0·5 millimeter thickness. Material and place, same as FIG. 13.

FIG. 15*a*.—Magnification, 50 diameters. Vertical light through plane glass of 0·5 millimeter thickness. Represents the left half of FIG. 16. Rail steel. Etched one minute in double chloride of copper and ammonium, 1 : 12.

FIG. 15*b*.—Magnification, 50 diameters. Vertical light through plane glass of 0·5 millimeter thickness. Position of object changed to the right of 15*a*.

FIG. 16.—Magnification, 50 diameters. Objective, 35. Vertical light through plane glass of 0·2 millimeter thickness. The left half corresponds to FIGS. 15*a* and 15*b*. Rail steel. Etched one minute in double chloride of copper and ammonium, 1 : 12.

FIGS. 17, 18 and 19.—Described in the text.

REMARKS BY THE TRANSLATOR.

Ingenieur E. Heyn's communication is a most valuable and timely contribution to the subject of metallography in general, and the discussion of the paper by Mr. A. E. Outerbridge, Jr., in particular. It shows how large and fertile a field for exploration the new science of metallography presents. Nevertheless, while Mr. Heyn is eminently right in saying that the structure of the specimens to be examined is not changed by the method of etching and examination, it is admitted that the *appearance* of the structure may not be the same under similar circumstances, unless certain precautions are observed. Mr. A. Sauveur, commenting on the paper by Mr. Outerbridge, and the discussion following, in the last number of the *Metallographist*, Vol. II, No. 2, April, 1899, pp. 152, 153, admits the validity of Mr. Outerbridge's plea for uniform methods, when he says: "It, however, remains true, doubtless, that similarity of treatment is as desirable in the case of metallographic methods as in the case of physical or chemical methods; but to the editor's mind the danger of "being misled" by the use of unlike processes is, if anything, less than in the case of the latter.

The writer fully agrees with the opinions expressed both by Engineer Heyn and Mr. Sauveur, but takes the liberty to point out that, while, as all roads lead to Rome, so all the various methods employed by the individual and scientific metallographist lead eventually to the same results, in order to make this new science practically useful for the everyday uses of the engineer, we must boil all these various methods down to something simple enough, and yet approximately accurate enough in its results, so that the work of the scientist not only becomes of greatest economic value to the community at large, but is comparatively easy of interpretation and comparison by those whose object is the immediate application of the results of microscopic examination for the purpose of rectifying defective treatment of metals in the mill, shop or erecting yard, and, if necessary, allow duplication of methods in such a manner and reasonable time as to convince persons not so well versed in all the intricacies of scientific metallography, nor in the complex phenomena of the properties of metals; that the results of such findings may be made comprehensible and acceptable to the minds and understanding of the many.

(Communicated by Mr. Albert Sauveur, Boston, Mass.)

MR. SAUVEUR:—From Mr. Outerbridge's paper and the appended discussion, one cannot help to gather the impression that the author and the participants to the discussion rather deplore the fact that the appearance of the structure of a metal, as revealed by the microscope, varies with the treatment to which the metal has been subjected. They are apparently inclined to look upon this in the light of a shortcoming which must diminish the value of metallographic methods applied to the testing of metals and alloys. Mr. Outerbridge points out that such variation of micro-structure, brought about by variation of treatment, may be misleading; he calls it "a source of error." The micro-structure of a metal undoubtedly varies with the treatment it has undergone, sometimes to a very great extent, but this is a fortunate occurrence, for the physical properties of the metal also vary, under the same conditions, in a no less marked degree. If the microscopical appearance of the structure were to remain the same whatever the treatment, the microscope would be as helpless as is chemical analysis in assisting us to solve the numerous and important problems presented by the heat treatment of metals. Its field of usefulness would be greatly curtailed, for it is precisely here, where chemistry fails us, that the assistance of metallographic methods becomes valuable; the slightest changes of heat treatment, which are always accompanied by corresponding variations of physical properties, record themselves in the structure of the metal; it only remains for us to learn how to read and to interpret these changes; and to this end the efforts of metallographists should bend.

It is evident that if we wish to compare the relative qualities of two samples of the same metal from the appearance of their micro-structure, the samples should be prepared under exactly the same conditions. We could not expect to derive any useful comparative datum from the microscopical examination of a sample cut from a small ingot, and therefore quickly cooled, and of a sample from a large ingot, and therefore cooled more slowly. The two samples do not have the same physical properties, and we would not think of passing judgment upon the relative value of the metals they represent, from the results they would give in the testing machine. To insist upon this point is superfluous.

Attention is also called in the paper and in the discussion to the fact that the appearance of an etched specimen will vary with the etching fluid, time of immersion, etc. It is undoubtedly true, but the wonder is that the structure will stand so much ill-treatment before being hopelessly disfigured. Mr. Outerbridge's specimens, I think, were all too deeply etched; and while a deep etching is sometimes desirable and useful, it must be remembered that it always blurs the lines of demarcation between the structural components, which otherwise would be sharp and clear. If similar liberties were taken with some analytical methods, the results would probably be disastrous, and the identity of the samples, as ascertained by their composition, irretrievably lost.

I could not be as lenient as the author towards the observer who would infer that his (the author's) photographs were taken from different specimens; indeed, I would be more inclined to pardon him for believing that the reproductions were all made from the same photograph, so great, it seems to me, is the similarity between them, judging, at least, from the half-tone engravings.

There is a tendency on the part of the author and of the participants to the discussion to exaggerate the danger of being misled by defective treatment of the specimens. After a short apprenticeship, and a fair degree of skill and good judgment, there will be very little difficulty experienced in preparing polished sections for microscopical examination, in such a way as to reveal the true constitution of the metal, free from all markings or blemishes foreign to its structure, or if any such irregularity appears to readily detect it. And, indeed, so long as this result is reached, it matters little what method has been used. It, however, remains true, doubtless, that similarity of treatment is as desirable in the case of metallographic methods as in the case of physical or chemical methods; but, to my mind, the danger of "being misled" by the use of unlike processes is, if anything, less than in the case of the latter.

MR. OUTERBRIDGE:—One purpose of the paper entitled "A Study of the Micro-structure of Bronzes" was, as stated therein, to invite criticism and discussion, and the author is pleased to observe that this invitation is being so generally accepted.

He finds it difficult, however, to understand how Mr. Sauveur could have inferred that the author, and the participants in the discussion on his paper, "deplore the fact that the appearance of the structure of a metal, as revealed by the microscope, varies with the treatment to which the metal has been subjected * * * they are apparently inclined to look upon this in the light of a shortcoming which must diminish the value of metallographic methods applied to the testing of metals and alloys."

The main object of the paper was to indicate the vital importance of showing with perfect accuracy the variations of micro-structure of various metals which have been subjected to different heat treatment, mechanical treatment or metallurgical treatment. Having noticed in his own studies that the records of such treatment may be unintentionally falsified by different methods of preparing the specimens for examination under the microscope, the author endeavored to show by argument and illustration the importance of adopting uniform methods of etching and polishing such specimens. Mr. Sauveur appears to have misinterpreted entirely the plain meaning of the argument; yet, later on, he agrees with its real purport, for he says: "It is evident that if we wish to compare the relative qualities of two samples of the same metal from the appearance of their micro-structure, the samples should be prepared under exactly the same conditions."

This is the crux of the whole argument in the original paper, and it was there stated that the numerous valuable contributions to the subject of microscopic metallography, illustrated with half-tone engravings, which have been published during the past ten years or more, are not easily comparable with each other, simply because one does not know whether the specimens have been prepared under exactly the same conditions; indeed, there are good reasons for believing that they have been prepared under very different conditions.

Mr. Sauveur thinks that the six half-tone illustrations accompanying the paper, showing six photo-micrographs of the same spot of the same specimen, taken after successive etchings, look so much alike that "one might believe that the reproductions were all made from the same photograph." The author selected for this purpose, as stated in the paper, a specimen which had certain characteristic groupings of dark bands in order that they might be readily recognized in each picture; the difference in appearance of the specimen after each etching was to be looked for in *the detail*, which was, of course, more clearly apparent in the specimen as observed under the microscope than in the half-tone reproductions made from photographic negatives.

Mr. Sauveur says, in conclusion: "Similarity of treatment is as desirable in the case of metallographic methods as in the case of physical or chemical methods." This is practically all that was contended for in the original paper.

The science of microscopic metallography is assuming an important position in industrial laboratories, and free criticism of the author's paper on the subject may prove far more valuable in clearing up uncertain points than did the original thesis. For this reason the author hopes that others may criticise his paper more vigorously than Mr. Sauveur has done. He is highly gratified that his comparatively unimportant and wholly tentative observations in "A Study of the Micro-Structure of Bronzes" should have drawn forth, from the distinguished engineer in charge of the Micro-Metallurgical Bureau of the famous Charlottenburg testing laboratories, one of the most valuable contributions to the science of microscopic-metallography that has appeared in any American publication.

CHEMICAL SECTION.

Stated Meeting, held December 6, 1898.

REACTION VELOCITY.

By Dr. Robt. Hart Bradbury,
Member of the Institute.

The speed of a body moving uniformly is the distance passed over divided by the time taken to pass over it—

$$v = \frac{s}{t}.$$

If the motion of the mass be not uniform, the division of the whole distance by the whole time will give simply the average speed and the velocity will be different at different points of the course. If we divide a small portion of the course, *e. g.*, 1 centimeter, by the time taken to traverse it, the result will be the average velocity over that centimeter and the variation in speed will be small; the approximation to the real velocity in that portion of the course will be close. Finally, if we consider an infinitely small portion of the path, ds, it is clear that the increment of velocity in passing over it will be an infinitely small quantity of the second order, or, in other words, the quotient of an element of a path by the infinitely small time taken to traverse it,

$$\frac{ds}{dt},$$

is the rigorous mathematical expression for the speed.

Now, the law of mass action, which is the foundation of our knowledge of chemical equilibrium and of the velocity of chemical changes, asserts that the speed of a chemical process is proportional to the product of the concentrations of the reacting substances, each concentration being affected by an exponent which is equal to the number of molecules of that constituent which takes part in the change.

$$v = kC_1^{n_1}C_2^{n_2} \ldots C_r^{n_r}.$$

This gives the speed of transformation from left to right in the chemical equation for the change.

For instance, if we consider the change of alcohol and acetic acid into acetic ester and water, the speed in the sense of the equation,

$$C_2H_5OH + CH_3CO_2H = CH_3CO_2C_2H_5 + H_2O,$$

is expressed by

$$v = kC_1C_2,$$

since we have but two concentrations to consider, and since both substances enter the change with one molecule. By the concentration we understand the quantity in unit volume, expressed in gram-molecules.

Many chemical changes are reversible, *i. e.*, they proceed from right to left, as well as from left to right; the reaction products interact and reform the original substances. Thus, if we mix equivalent quantities of water and acetic ester, chemical transposition occurs and some acetic acid and alcohol are produced.

In reversible changes the direct reaction, *e. g.*, the production of ester and water from the alcohol and acid, and the reverse reaction, *e. g.*, the production of alcohol and acid from the ester and water, must be considered to occur together in the liquid. The observed velocity at any time is the difference of the two. Writing v' for the speed of the reverse change there.

$$v' = k'C_1'C_2'.$$

Where C_1' and C_2' are the concentrations of the ester and the water, and if V is the observed speed, then

$$V = v - v' = kC_1C_2 - k'C_1'C_2'.$$

Introducing the possibility that each of the substances may enter the change with more than 1 molecule and making the number of substances unlimited, we have for the most general expression for the observed speed of change

$$V = v - v' = kC_1^{n_1}C_2^{n_2}C_3^{n_3} \ldots - k'C'^{n'_1}_1C'^{n'_2}_2C'^{n'_3}_3.$$

In practice matters are greatly simplified by the facts that the exponents n_1, n_2, etc., are always small numbers—no case is known where $n > 3$; that the number of substances which can simultaneously take part in a change is small, three being at present the limit in this case also; and that in many reactions the speed of the reverse reaction from right to left is so small, that it can be left out of account without introducing any serious error.

We have now to examine more narrowly the meaning of the term velocity, as applied to chemical changes. Instead of distance passed over, we have here to introduce the idea of quantity transformed and our unit, instead of centimeters, becomes gram molecules. If x is the quantity transformed in unit volume at any time, and t the time, then the average velocity for the time elapsed is

$$\frac{x}{t}$$

But the speed of a chemical change is a variable magnitude: theoretically it begins with its maximum value and sinks gradually to zero; hence the mathematical expression for velocity is the relation of an infinitely small quantity transformed to the infinitely small time taken to transform it, the differential coefficient of quantity by time.

$$\frac{dx}{dt}.$$

In the following formulation we shall make the assumption that the reaction proceeds in but one direction, or that the speed of the reverse change may be neglected.

Restricting the discussion to unit of volume, it is clear that if the concentrations of the several molecular species at the beginning are A, B, C, etc., that their concentrations after a time, t, during which a quantity, x, in gram molecules has been transformed, will be (A — x), (B — x), etc., and the velocity of the change at the time will be

$$\frac{dx}{dt} = k\,(A - x)\,(B - x)\,(C - x), \text{ etc.}$$

This expression becomes much simpler in the case where the concentrations of all the species, taken as always in gram molecules, are the same at the beginning—and where each enters the reaction with a single molecule. In this case the concentration of each species will remain the same through the process. That is (B — x), (C — x), etc., will equal (A — x), and the velocity is

$$\frac{dx}{dt} = k\,(A - x)^n$$

where n is the number of substances which enter into the reaction. Or, in words: the velocity is proportional to the product of the concentrations of the reacting substances. In the case above, where the concentration of each of the substances is (A — x), we may call this the system-concentration, and the velocity is then proportional to the system concentration affected by an exponent which is equal to the number of reacting substances. Using this simplification, we have for the reaction in which the concentration of but one substance is made to vary the reaction of the first order, as Ostwald calls it, or the monomolecular reaction according to Van't Hoff

$$\frac{dx}{dt} = k\,(A - x).$$

For a reaction in which two substances enter in molecular proportions, reaction of the second order of Ostwald, bimolecular reaction of Van't Hoff,

$$\frac{dx}{dt} = k\,(A - x)^2.$$

Finally, for a reaction in which the concentration of three substances is affected, reaction of the third order of Ostwald or trimolecular reaction of Van't Hoff,

$$\frac{dx}{dt} = k\,(A - x)^3.$$

Reactions in which four or more molecules are concerned are unknown.* One obtains an excellent idea of the progress of a chemical change by integrating these equations, and then making the "graph" of the resulting functions, laying off x on the axis of ordinates and t on the axis of abscissas.†

The course of the reaction is represented by a curve which rises from the time axis at first abruptly, then bends over to the right and ends by approaching asymptotically a line parallel to the time axis. The curve for the monomolecular reaction lies above that for the bimolecular, and this in turn above the curve for the trimolecular. These curves have no maxima and minima and no points of inflection, but this, of course, is evident from the differential equations, without recourse to the "graph."

The final state of things is $x = A$, that is, all the substance has been transformed. This state must evidently be reached with a velocity of zero, and cannot be passed. There is thus no inertia in a chemical change, no oscillation about the position of equilibrium, analogous to the vibration of a distorted solid.

Historically the first chemical change which was subjected to quantitive treatment was the inversion of sugar. The date of Wilhelmy's work on this subject, 1850, is an important one to chemical science, for until that time our science had contented itself almost entirely with acquiring information about the final products of chemical changes, and the problem of studying the change itself had not been successfully attacked.

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* Very recently a tetramolecular reaction has appeared. Compare Judson and Walker, *Journ. Chem. Soc.*, 73,410 (1898). A brief account of their work is given in a supplementary page.

† Ostwald, *Lehrbuch*, Vol. II, Part II, p. 228.

To devise the first successful mathematical description of a chemical change was undoubtedly a great achievement, and the very important work in reaction velocity which has been done within the last twenty-five years by Van't Hoff, Ostwald, Noyes and their students, is an outgrowth entirely of the seed which Wilhelmy planted.*

The inversion of sugar takes place under the influence of hydrogen ions and with absorption of a molecule of water. The concentration of the hydrogen ions is not altered, their action being catalytic, and the water is present in such large quantity relatively to the sugar that its concentration may be considered constant. The influence of these substances is the same throughout the change, and is incorporated in the constant k.

The change is therefore monomolecular, and is described by the equation

$$\frac{d\,x}{d\,t} = k\,(A - x)$$

In order to test the equation, to prove that it does as a matter of fact, describe the progress of the reaction in time, it is necessary to integrate it, to solve for k, and to ascertain whether k is in fact constant through the whole of the change.

Integrating we get

$$-\log.\,(A - x) = k\,t + C.$$

C, the constant of integration, is easily eliminated by recalling the fact that x, the change in concentration of the sugar and t, the time, are both zero at the beginning.

Introducing this condition we have

$$-\log.\,A = C, \text{ and}$$

$$k = \frac{1}{t}\log.\frac{A}{A - x}$$

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* Wilhelmy's original paper has been reprinted with notes by Ostwald, *Klassiker d. Exakten Wissenschaften*, No. 29.

All the quantities in this expression for k are known or may be determined; t is simply the elapsed time.

A is the original concentration of the sugar, and x is easily ascertained at any moment by the polariscope. The results showed that the value of k is in fact constant, and that the differential equation must be regarded as a valid description of the change.

The differences in the value of k (from ·001321 to ·001499) are due to variations in temperature of the solution.

Temperature has a great influence on reaction velocity, and at present in all work of this kind the temperature of the solution is carefully maintained constant.

Another classical case of the monomolecular reaction is the decomposition of arsine. From the chemical equation

$$4AsH_3 = As_4 + 6H_2$$

we might predict that the reaction would require the simultaneous meeting of four molecules, and would be tetramolecular.

Such a change would be described by the equation

$$\frac{dx}{dt} = k(A - x)^4$$

It has already been remarked that no tetramolecular reaction is known. In fact, trimolecular reactions are extremely rare. The reaction in question is eminently monomolecular, and the same logarithmic formula employed for the sugar inversion, gives values for k which are remarkably constant.

So far, the kinetic theory of the molecule has not been of much value in dealing with chemical phenomena. Nevertheless, a recent remark of Van't Hoff is of interest in this connection. The slow progress of a monomolecular reaction of this kind shows that not all the molecules are in the same condition. If they were, either none would decompose or they would all decompose at once. This reminds us of Maxwell's conception that the molecules of a gas possess all possible temperatures distributed about the mean value.*

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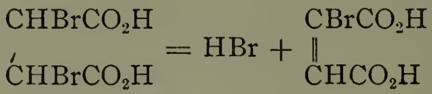
* *Vorlesungen über Theoret. Chem.*, Vol. I, p. 187.

Another distinctly monomolecular reaction is the splitting up of di-brom-succinic acid into mono-brom-maleic acid and hydrobromic acid.



$$\begin{array}{l} CHBrCO_2H \\ | \\ CHBrCO_2H \end{array} = HBr + \begin{array}{l} CBrCO_2H \\ \| \\ CHCO_2H \end{array}$$

*

The bimolecular reaction.

In this case the concentration of two substances is changed as a result of the reaction, hence the equation is

$$\frac{d\,x}{d\,t} = k\,(A - x)^2$$

Integrating we obtain at once

$$\frac{1}{A - x} = k\,t + C$$

and remembering that x and t are simultaneously zero,

$$\frac{1}{A} = C$$

$$k = \frac{x}{A\,t\,(A - x)}$$

The reactions whose progress is described by this formula are numerous. Among the most important are the saponifications of the esters; for instance, the action of sodium hydroxide on acetic ester, which, in the usual notation, is:

$$CH_3COOC_2H_5 + NaOH = CH_3COONa + C_2H_5OH$$

or in terms of the theory of electrolytic dissociation,

$$CH_3COOC_2H_5 + O\overline{H} = CH_3C\overline{OO} + C_2H_5OH$$

Reactions of this type have been investigated with special thoroughness by Warder, Reicher, Ostwald and Arrhenius, and it has been shown that, in general, the reac-

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* *Van't Hoff-Cohen.* "*Studien zur Chemischen Dynamik,*" p. 117; where there is an interesting instance of the possibility of detecting the presence of a mixture of isomers by investigation of the reaction velocity.

tion is bimolecular. Among other bimolecular reactions is the hydrolysis of acetamide by acids *e.g.* *

$$CH_3CONH_2 + H_2O + CCl_3COOH = CH_3COOH + CCl_3COONH_4$$

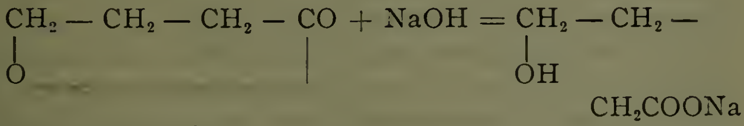
This is apparently trimolecular, but the water is present in such large quantity that its concentration may be considered constant. Further, the reaction between sodium hydroxide and sodium mono-chlor-acetate,

$$CH_2ClCOONa + NaOH = CH_2OHCOONa + NaCl,$$

investigated by Schwab, under Van't Hoff's direction.†

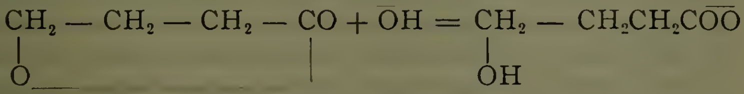
Some of the most interesting of the recent work in this field is the investigation of the action of bases upon γ and δ lactones, carried out in Ostwald's laboratory, by Paul Henry.‡

From the older standpoint the reaction is, for butyro-lactone



$$\underset{\underset{O}{|}}{CH_2} - CH_2 - CH_2 - CO + NaOH = \underset{\underset{OH}{|}}{CH_2} - CH_2 - CH_2COONa$$

or, more accurately,



$$\underset{\underset{O}{|}}{CH_2} - CH_2 - CH_2 - CO + \overline{O}H = \underset{\underset{OH}{|}}{CH_2} - CH_2CH_2CO\overline{O}$$

In either case the reaction is accomplished by the meeting of two molecules, both of which are reduced in concentration as a result, and is therefore bimolecular. Henry placed 190 cubic centimeters of a solution of the base to be investigated, $NaOH, KOH, Ba(OH)_2$ etc., in a thermostat, and added 10 cubic centimeters of a $\frac{1}{10}$ normal solution of the lactone. The concentration of the base was so chosen that it became $\frac{1}{200}$ normal by the additional dilution to 200 cubic centimeters, the lactone, of course, be-

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[*] Ostwald, *Lehrbuch d. All. Chemie*, Vol. II, Part II, p. 215.

[†] *Studien zur Chemischen Dynamik*, p. 14.

[‡] *Zeitschrift für Phys. Chemie*, *10*, p. 96.

coming $\frac{1}{200}$ normal at the same time. After the lapse of a time, t, counted in minutes, the value of x was determined by titrating the remaining alkali with dilute hydrochloric acid of known strength. In the case of the strong bases, potassium, sodium and barium hydroxides, the values of k were constant within the limits of error. With the weak bases a different behavior was to be expected: thus with ammonia, it is obvious that ammonium ions must accumulate in the liquid during the process; this will force back the dissociation of the ammonium hydroxide, reduce the concentration of the hydroxyl ions and cause the value of k to diminish with increasing time. In conformity with this, it was found that with ammonium hydroxide and methylamine hydroxide the value of k decreased as the time increased. It is interesting to notice the verification of another prediction of the theory of electrolytic dissociation. Since the stronger bases are dissociated with practical completeness at moderate dilutions, it was to be expected that no increase in their efficiency in converting the lactones into salts of the γ-oxy-acids would be noticed with increasing dilutions; with ammonia or other weak bases, we should expect increasing dissociation and increasing values of k. This conclusion was strikingly verified by experiment. Finally, we must notice Henry's interesting experiments on the saponification of acetic ester by barium hydroxide. In this case the old and the new view of the state of substances in solution make opposed predictions. From the older point of view the reaction is

$$Ba(OH)_2 + 2CH_3COOC_2H_5 = Ba(C_2H_3O_2)_2 + 2C_2H_5OH.$$

Here, since the ethyl acetate enters, the reaction with two molecules, and the baryta with one, the speed is given by an equation of the form

$$\frac{d\,x}{d\,t} = k\,(A - x)^2(B - x) \qquad (1)$$

where A is the original concentration of the ester and B that of the base.

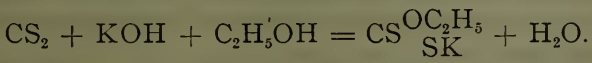
On the other hand, according to the more recent conception, the reaction is

$$CH_3COOC_2H_5 + \bar{O}H = CH_3CO\dot{O} + C_2H_5OH,$$

and requires an equation of the simple form

$$\frac{dx}{dt} = k(A - x)(B - x), \qquad (2)$$

A being again the concentration of the ester and B that of the hydroxyl, which, of course, is the same as the equivalent concentration of the base. The results showed that it was possible to get constant values of k by means of a form of equation (2), indicating that the hydroxyl ions exist free in the liquid, and that it is to them that the basic properties are due. In all work of this kind it is indispensable to keep the temperature constant; otherwise constant values of k cannot be obtained. Moro* investigated the production of the alkali salts of ethyl-sulpho-thio-carbonic acid from carbon disulphide, alcohol and potassium or sodium hydroxide



$$CS_2 + KOH + C_2H_5OH = CS\genfrac{}{}{0pt}{}{OC_2H_5}{SK} + H_2O.$$

The purpose of the research was to find a typical trimolecular reaction, in which the three substances were different. This was not attained, because it was found necessary to work in dilute alcoholic solution, which, of course, made the concentration of the alcohol constant. In the case of the potassium salt, satisfactory constants were not obtained, but the reaction is probably bimolecular.† Bimolecular also were the reactions in which the same xanthates were produced from carbon disulphide and potassium or sodium ethylate:

$$C_2H_5OK + CS_2 = CS_2OKC_2H_5.$$

For the trimolecular reaction, making the same restrictions as before, that the speed of the reverse change may be neglected and that the equivalent concentrations of the three substances are constantly the same, we have

$$\frac{dx}{dt} = k(A - x)^3$$

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* *Gazzetta Chimica Italiana*, Vol. XXVI, p. 494 (1896).

† Curiously enough, with the sodium salt the reaction is accurately bimolecular.

Integrating

$$\frac{1}{2(A-x)^2} = k\,t + C.$$

The value of the constant of integration is again given by the fact that x and t are simultaneously zero. This gives us

$$\frac{1}{2\,A^2} = C$$

$$k = \frac{1}{2\,t}\left(\frac{1}{(A-x)^2} - \frac{1}{A^2}\right)$$

or

$$k = \frac{1}{t}\left(\frac{2\,A\,x - x^2}{2\,A^2(A-x^2)}\right)$$

Trimolecular reactions are rare; nevertheless, the three possible types are all known. The case where the three molecules are the same is represented by the polymerization of cyanic acid

$$3CNOH = C_3N_3O_3H_3,$$

which has been studied by Van't Hoff. Two molecules of one substance react with one of another in the reduction of ferric chloride by stannous chloride, the basis of the well-known rapid volumetric method for iron

$$2FeCl_3 + SnCl_2 = 2FeCl_2 + SnCl_4.$$

This reaction has been shown to be trimolecular by Noyes. Finally, all three molecules are different in the oxidation of ferrous chloride by potassium chlorate and hydrochloric acid,

$$KClO_3 + 6HCl + 6FeCl_2 = 6FeCl_3 + 3H_2O + KCl.$$

According to the chemical equation, this change requires the simultaneous meeting of thirteen molecules; yet the researches of Noyes and Wason leave no doubt that it is trimolecular.

[*To be concluded.*]

FRANKLIN INSTITUTE.

Stated Meeting, held March 15, 1899.

GRAPHITE: ITS FORMATION AND MANUFACTURE.

By E. G. Acheson,
Member of the Institute.

EARLY HISTORY AND RECOGNITION.

In the year 1779, Karl Wilhelm Scheele, a young apothecary in the town of Koping, Sweden, a remarkable genius as an investigator, and then in the 37th year of his age, discovered that graphite had an individuality quite apart from molybdenum sulphide, with which it had been until then confounded. He discovered that when it was treated with nitric acid, carbon dioxide was produced, whereas molybdenum sulphide when oxidized produced a white earth, and he drew the conclusion that it must be some kind of carbon, likely of the general nature of coal.

Previous to this discovery by Scheele, a group of minerals including graphite and certain ores of lead, molybdenum, antimony and manganese (lead sulphide, molybdenum sulphide, antimony sulphide, manganese dioxide) were believed to be one and the same substance, or, at least, members of the same family. This opinion was due to their outward resemblance, and the fact that they produced marks on paper. This confusion naturally led to the application of the same name or names to each of the members of the group, and as graphite had not been recognized by any peculiarity distinctively its own, it received the names molybdæna, plumbago, graphite and black-lead, which were used in an indiscriminate manner for each of the several substances. The name molybdæna was dropped at an early date, probably immediately following the discovery by Scheele, and there is no known reason why plumbago and black-lead should not have followed its lead, for graphite is the only one of the series not misleading and entirely appropriate, meaning as it does "I write," from the Greek word *γράφω*.

Graphite does not seem to have received any particular attention from chemists from the time of the discovery by Scheele until the year 1800. During the last quarter of the eighteenth century, the diamond was a subject of much interest, in a chemical sense, and in the hands of the French chemists it was shown to produce carbon dioxide when ignited in air. In 1796 Smithson Tannant showed that equal weights of charcoal and diamond yielded equal weights of carbon dioxide on burning, and they were thereafter associated together as carbon. In 1800 Mackenzie added graphite to the carbon group, by showing that it also, in equal weight, produced the same weight of carbon dioxide.* Thus, in the opening year of the present century, graphite was proven to be an elementary substance. Charcoal, diamond and graphite were then recognized as three distinct allotropic forms of the element carbon.

DISTRIBUTION.

Graphite, in a more or less pure state, is quite freely distributed over the earth, but only in a few places is it found under conditions of purity, quantity, ease of mining, refining and transportation to market that permit of a profitable business being made of it. Statistics for the six years 1890 to 1895, inclusive, give the world's production as 73,751, 57,220, 54,280, 55,810, 46,951 and 53,955 short tons. This is an average yearly production of 56,994 tons—over 156 tons every day of the year—of a material known to the majority of men as black-lead or plumbago, useful only for writing on paper and polishing stoves.

The production during the years mentioned was contributed to by Austria, Ceylon, Germany, Italy, United States, Canada, Japan, India, Russia, Great Britain, and Spain, the proportionate quantities furnished by these countries being in the order given.† It will be observed that Great Britain is, with but one exception, the smallest producer; indeed, 45 tons cover the total amount reported, and this was mined in 1895. For several centuries Great Britain was one of, or the, largest producer; in fact, in the earliest days of the industry, it was probably the only one. The graphite from the Borrowdale mines in Cumberland was famous as the best for making pencils. In the sixteenth and seventeenth centuries these mines were so productive as to yield an annual revenue of £40,000, although they were only worked a few weeks in the year for fear of exhausting them.*

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* Roscoe.

† *Mineral Industry*, 1898.

Great differences exist in the structure and purity of the graphites furnished from the various mines. Mother Nature was seemingly not content with making carbon appear in three forms—charcoal, diamond and graphite—but extended her labors on graphite; and, to the further confusion of the metallurgist and the chemist, made it a family of two members, crystalline and amorphous, two distinct allotropic forms of the allotropic substance, graphite. The product of the Ceylon mines is crystalline, of great purity, analyzing in some instances over 99 per cent. carbon, while that of the Borrowdale mines is amorphous and also very pure.

The chief impurity in graphite is iron; indeed, its constant presence and frequent large quantity led to the belief, in the early days, that graphite was a carbon-iron compound, and it was even sometimes called carburet of iron.

USES.

It is quite probable that the first use made of graphite was as an instrument for writing. The first account we have of its employment for this purpose is contained in the writings of Conrad Gessner on Fossils, published in 1565. A picture of a pencil is shown, and, referring to it, he says: "The pencil represented below is made, for writing, of a certain kind of lead (which I am told is an artificial substance termed by some, English antimony), sharpened to a point and inserted in a wooden handle."† This pencil was probably made of graphite from the Borrowdale mines, which, we are told, were in operation in the sixteenth century. Its uses for other purposes than pencils are of much more recent date, probably all of them falling within the present century, and nearly all within the last few years.

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* Roscoe.

† Roscoe.

The present uses of graphite include the manufacture of pencils, crucibles, stove polish, foundry facing, paint, motor and dynamo brushes, anti-friction compounds, electrodes for electro-metallurgical work, conducting surfaces in electrotyping, and covering the surfaces of powder grains. For most of these purposes it is used in the natural impure state, while for others it is necessary to render it quite pure and free from grit. Its purification is accomplished by a method worked out by Brodie, which consists in first grinding, or otherwise reducing the graphite to a state of fine subdivision, washing out the heavier impurities, mixing 14 parts with 1 part of potassium chlorate and 2 parts of concentrated sulphuric acid, heating on a water-bath for some hours, washing thoroughly and afterwards roasting at a red heat. If silica is present a treatment with hydrofluoric acid is added to the process.

The mining and manufacture of graphite into articles for which it has been found useful, give employment to thousands of people. The mines of Ceylon alone, when working to their capacity, employ about 24,000 men, women and children; the work, however, is done entirely by hand, and in a very crude manner.* In the city of Nüremburg, Germany, the home of the famous Faber pencil, are twenty-six factories, employing about 5,500 people in the making of pencils.†

MANUFACTURE.

The rapid increase in the use of graphite and consequent decrease in Nature's stocks, make the problem of manufacturing it to order, a subject of much importance.

When we consider the hundreds of thousands of chemical changes men are constantly putting the elementary bodies through, and the very prominent part taken by carbon in these reactions, it would be rather remarkable if at some point, Nature's method for producing graphite was not discovered. That it is not a very difficult act is evident from the fact that it has been accomplished, in a small way, in several instances.

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* "Watt's Dic. of Chem.," 1890.

† "Encl. Brit."

Mr. Muir, in Watt's Dictionary of Chemistry, edition of 1890, mentions six recognized methods.

(1) By heating charcoal with molten iron, and dissolving out the iron with hydrochloric and nitric acids.

(2) By the slow decomposition of hydrocyanic acid, and boiling the product with nitric acid.

(3) By evaporating the mother liquors obtained in making soda: these contain cyanogen compounds which are decomposed at a certain concentration of the liquid with formation of ammonia and graphite.

(4) By leading carbon monoxide over ferric oxide at 300° to 400°.

(5) By the decomposition of carbon disulphide at high temperature, in contact with metallic iron.

(6) By leading carbon tetrachloride over molten pig iron.

Whether or not any of these methods could be developed to a state providing a commercial process, I am not prepared to say, but am inclined to think not. They have always been considered accidents or chemical feats of the laboratory, and in some instances their formation was very objectionable.

The Cowles Bros., of Cleveland, O., are reported to have found that graphite sometimes occurred in or about the charge of an electric furnace. This formation is referred to in one of their patents, and a feature of the patent is a provision to get rid of the material, as it was very objectionable on account of its high electric conductivity. Its formation was not reduced to a method, the causes for, or the exact conditions under which it was made, not having been investigated. It was like some of those in the list of Muir, an accident, and a great nuisance.

Still another way of making graphite was described by G. Rose, in 1872. He exposed a cut diamond, bedded in charcoal, to a temperature equal to molten cast iron, whereupon the surface became coated with graphite. It is safe to say this process will never attain commercial success nor popularity.

Finally, in the Encyclopædia Britannica (1890) we are told that " by heating to the high temperature afforded by a powerful galvanic battery, both the diamond and amorphous carbon are converted into graphite." This statement I will refer to later on.

In a paper which I had the honor of presenting to the Institute at its stated meeting of June 21, 1893,* reference was made to the formation of a black material consisting of a mixture of carborundum and free carbon during the operation of the carborundum furnaces. This was again referred to, and at much greater length, by Mr. Francis A. Fitzgerald, chemist to the Carborundum Company, in a lecture delivered before the Institute on December 11, 1896,† after it had been the subject of much thought and study, and when I had about concluded the formulation of a theory covering the transformation of amorphous into graphitic carbon.

Very early in my experiments on the manufacture of carborundum, I noticed that graphite occasionally formed in the portion of the furnace charge lying next to the cylinder of granular amorphous carbon, which passed through the center of the furnace, and which became heated to an extremely high temperature, by the passage of a heavy electric current, and around which the charge was placed to receive the heat necessary for the formation of carborundum. Also that when ordinary bituminous coal coke was used to form the core, quite a large amount of it was converted into graphite, whereas, when petroleum coke was used, very little of it was made graphitic.

By a careful study of these formations, it was found that the graphite formed outside of and surrounding the core, was produced by the decomposition of the carborundum, which is, chemically, a carbide of silicon, and, by induction from a number of known facts, that that formed within the core was also produced from a similar decomposition of carbides, which were created by the chemical union of the carbon of the core with its contained impurities. The facts from which I have drawn this conclusion are:

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* "Carborundum: Its History, Manufacture and Uses."

† "The Manufacture and Development of Carborundum at Niagara Falls."

(1) Comparatively pure petroleum coke produces practically no graphite.

(2) Impure bituminous coal coke produces large quantities.

(3) The larger the known percentage of impurities in the bituminous coal coke, the greater the amount produced.

(4) That only a part of the carbon of the core is converted into graphite. This not being increased, even by repeated use of the same grains, in successive carborundum furnaces.

The graphite formed by the destruction of carborundum, is remarkable in that it retains the form of the crystal of carborundum from which it is derived. It has, however, less than one-third the weight of carborundum and possesses the characteristic metallic gray color of natural graphite, but in size and form it so closely resembles the original crystal as to be, in fact, its pseudomorph in graphite. The graphite formed in the core is usually not so well defined, or distinct, as in that from carborundum, most of it being disseminated through the body of the individual grains in which it is found, the amount contained in any one grain varying with the percentage of impurity originally present. In some instances, the entire mass of the grain is converted into beautiful graphite, this occurring, I think, in cases where the grain is largely composed of slate, and it sometimes happens that one-half of the grain is completely converted, while the remainder is changed but little.

These two seemingly distinct methods of producing graphite from carborundum and from coke, are, in fact, identically the same; the first step in each is the formation of a carbide, the second its destruction. In making carborundum, silica and coke are mixed in the correct proportions to produce a true carbide, when heated in the electric furnace, without an excess of either constituent. In making this mixture, account is taken of the impurities contained in the coke, and the silica reduced proportionately. In the case of the core, there is a natural mixture that produces a carbide from a portion of the carbon. The carbides formed under both of these conditions decompose when heated to a certain temperature above that at which they were formed.

This method of manufacturing graphite, I would define, as consisting in heating carbon, in association with one or more oxides, to a temperature sufficiently high to cause a chemical reaction between the constituents, and then continuing the heating until the combined carbon separates, in the free state. It is not, however, limited to the use of oxides, as pure metals, their sulphides and other salts may be used; but for various reasons the oxides are to be preferred.

THEORY OF FORMATION.

All of the methods of manufacture, thus far known, contain the same underlying, fundamental principle. Each of the six methods described by Muir, as well as my own method, contain as a part of the process, the expulsion or liberation of the carbon from a chemical association with one or more elements, and this occurs under conditions unfavorable to, or absolutely prohibitive of, its reassociation with the same or other elements. It is cast out, free to take unto itself such physical or other properties, as we must assume, properly belong to it in the free state, when formed under normal conditions. It has been shown by Moissan, that when subjected to great pressure, at the moment of separation from cast iron, carbon has those distinctive characteristics that cause it to be called diamond, while Scheele showed, in 1778, that the same carbon, separating from the iron without pressure, takes the graphitic form. Amorphous carbon, the third allotropic form, never occurs pure and is invariably produced from carbon held in chemical association with other elements, under conditions favorable to free chemical action between it and other elements.

The production of graphite by Rose's method—heating a diamond bedded in charcoal to the melting-point of cast iron—is a beautiful illustration of the return of a body under strain, to the form it takes under normal conditions. It will be noted that the diamond was heated to the temperature at which it is known to form, as shown by Moissan's experiments; also that it was fairly well protected from chemical action.

The statement in the Encyclopædia Britannica that both diamond and amorphous carbon are converted into graphite, when heated by a powerful electric current, is very commonly held, indeed, I might say universally, although Berthelot concluded, from his investigations, that heat alone is without influence on carbon: that is to say, graphite is not changed to amorphous carbon, nor the amorphous to graphite, when heated to whiteness in an atmosphere of hydrogen or chlorine. That diamond will change to graphite, when protected from chemical influences, under the influences of high temperature, is undoubtedly true, and, indeed, is what might be expected from other known facts; but that *pure* amorphous carbon will change to graphite as the simple result of heating, is not proven, and certainly it does not occur at, or below, the temperature necessary for the transformation of the carbon in a carbide, to graphite.

From the facts in hand, I have deduced the following theory:

(1) Graphite is the form carbon assumes, when freed from chemical associations, under conditions of low pressure and protection from chemical influence.

(2) Diamond is the form carbon assumes, when freed from chemical associations, under conditions of high pressure and protection from chemical influence. And, by inference,

(3) Amorphous carbon is the form carbon assumes, when freed from chemical associations, under conditions of low or high pressure and exposure to chemical influence.

This theory does not, however, account for all of the observed facts, and must be supplemented by the hypothesis that catalysis occurs, under certain conditions, during the transformation of amorphous into graphitic carbon. The amount of graphite produced in the core of a carborundum furnace, and also in graphite articles I have made, is much too great to be accounted for by the theory that it is formed by the dissolution of the fixed carbides, formed by the contained impurities and carbon sufficient to satisfy the chemical formula. The most probable and satisfactory explanation is that a catalytic action occurs—a progressive formation and dissolution of carbides. The temperature being much above the point of volatilization of silica, and all other possible impurities, a rapid dissipation of the active agents takes place and is completed, in this case, before the conversion of all of the amorphous carbon can occur.

COMMERCIAL MANUFACTURE.

As the result of my investigations and deductions, I think the only commercial way to make graphite is by breaking up a carbide by the action of heat. The carbon should be freed from chemical combination by what might be termed the evaporation of its associated elementary substances. I have secured patents covering this method, and these have been made the basis for the organization of an incorporated company, bearing the name "Acheson Graphite Company." The company has now under way the erection of works at Niagara Falls, where the necessary electric current will be obtained from the Niagara Falls Power Company.

Several distinct forms of the product will be produced. One consists of forms or articles, made out of amorphous carbon, with the desired amount of impurity added thereto, which will afterwards be heated in an electric furnace and converted, more or less, into graphite. I have been carrying on this line of manufacture for a year or more, using the furnaces of the Carborundum Company to produce the graphitization, the articles having first been made by the arc-light carbon manufacturers. Over 200,000 carbon electrodes, measuring 15 inches in length, with about 1 inch cross-sectional area, were made for use in the Castner alkali process, nearly one-half of them having been shipped to Europe, to be used for this work in England and Germany. The life or efficiency of these graphitized electrodes is many times that of the same electrodes ungraphitized. I have also graphitized some tons of carbon plates, to be used in making dynamo and motor brushes, and a large variety of odd forms and sizes for divers purposes.

Another product—the one which will probably be of greatest importance—is an intimate mixture of pure amorphous carbon and graphite in fine powder. This will be put on the market for paint and foundry facing, and, as it has been formed at an extremely high temperature, it is quite pure, and possesses all of the qualities desirable for the purposes for which it is intended.

It is not the present intention of the company to enter into the manufacture of their product into finished form for the general market, but rather to encourage those who are now engaged in making up the natural graphite into articles of commerce to become buyers of their material, substituting it for that now used.

The company's plans, now being carried out, provide for the erection of a brick-and-iron building, 100 x 50 feet, on a plot of ground in Block No. 8 of the Niagara Falls Power Company's lands (adjoining the works of the Carborundum Company). Therein they will erect machinery for reducing coke to grains of the desired size, an electric furnace through which the prepared grains will pass in a continuous stream, a pulverizer for reducing the grains as received from the furnace, and a scalping sieve through which the product from the pulverizer will pass, that particles exceeding the $\frac{1}{200}$ of an inch diameter may be removed. The final flour or powder will contain an amount of pure graphite proportionate to the percentage of impurities in the original coke. It is quite possible that, instead of using high-grade, marketable coke, the fine refuse from the coke ovens, which is at present a waste material, will be utilized in the manufacture of this product.

In this connection I would call attention to the need of a specific name for the new product. *Artificial*, as applied to a product, chemically and physically identical with that made by Nature, is not pleasing; it conveys the impression that, failing to produce the real thing, a cheap imitation, a sham, is being palmed off as the genuine article. Not even the Century Dictionary's definition of artificial, as "made or contrived by art, or by human skill and labor; opposed to Nature," is sufficient to banish this feeling; for, after all, in the particular case in hand, being ignorant of the exact methods pursued by Nature, we may be simply forcing her to reveal her methods, to the final results of which we neither add nor subtract one jot or tittle. The same objections may be made to the expression *artificial manufacture* of Graphite, for we may not be sure that the process forced upon her is not identical with that of her own selection. *Manufactured graphite* would be quite appropriate, were it not for the fact that it is popularly applied to articles made of graphite.

It may not detract from the general interest in this subject to call attention, in closing, to the fact that graphite, first shown to be an elementary body, an allotropic form of carbon, in the first year of the nineteenth century, is in this, the last year, made to order in great quantities, and that it will, before the close of the century, become an article of ordinary commerce in its new form. Perhaps it will take its place as the primitive form of carbon—the one it assumes under normal conditions.

NOTES AND COMMENTS.

ARTIFICIAL ALBUMIN.

In the London *Chemical News*, Mr. Alfred H. Allen questions the accuracy of the published reports respecting the artificial production of a laboratory product identical with albumin, which was credited to Dr. Leo Lilienfeld at the recent International Congress of Applied Chemistry at Vienna.

This announcement was received with unusual interest, because of the possible incalculable value of a practicable method of forming in the laboratory this product which is the fundamental constituent of all nitrogenous (or flesh-forming) foods.

Mr. Allen comments on the subject in the following terms:

" From the accounts which have hitherto come to hand, it appears that it is not true albumin of which Dr. Lilienfeld claims to have effected the synthesis, but 'peptone,' which is a very different thing. It is said to be produced by the condensation of glycocine (amido-acetic acid) with phenol, by means of phosphorus oxychloride. The reaction is said to occur quantitatively and with great facility, allowing of the whole process being shown at the meeting. Further, Dr Lilienfeld is said to have demonstrated, by the most conclusive tests, the absolute identity of his product with natural peptone, or—according to some accounts—with true albumin. Seeing how very ill-defined are the chemical tests for 'peptone,' and that more than one kind of peptone is recognized, this part of the account must be received with caution. Still more doubt attaches to the statement that Dr. Lilienfeld's product has the same elementary composition as natural peptone (or albumin). Seeing that natural albumin and peptone both contain sulphur as an essential constituent, and that Dr. Lilienfeld's process does not involve the employment of sulphur in any form, there seems to be a screw very loose somewhere.

"Although the description of the mode of formation of Lilienfeld's body appears to negative the conclusion that he has effected the synthesis of either albumin or peptone, it by no means follows that he has not produced an albuminoid substance of great theoretical interest." W.

DOES IT PAY TO BUILD LARGE TELESCOPES?

Prof. George E. Hale, a noted American astronomer, answers this question by summarizing the principal advantages of a large telescopic object glass—40 inches aperture in the special case as compared with a smaller one of 10 inches.

These advantages consist:

(1) In the fact that the larger glass is capable of giving much brighter star images, and thus of rendering visible faint stars that cannot be seen with the smaller glass.

(2) In the fact that it gives at its focus an image of the object enlarged in proportion to its greater diameter.

(3) In its capacity to render visible, as separate objects, the components of very close double stars or minute markings on the surface of a planet or satellite.

The principal disadvantage of the large glass is that it demands better atmospheric conditions to bring out its best qualities.

He adduces several important astronomical discoveries which have been made possible only with the aid of large glasses, viz.: the discoveries of the fifth satellite of Jupiter and of the two satellites of Mars. Furthermore, the author declares that much fine detail which he has never been able to see with the smaller glass, is "clearly and beautifully visible" with the 40-inch glass. Also, he states, micrometrical measurements are effected with much more ease and certainty with the large instrument.

"It is particularly in astrophysical research that a great telescope is advantageous. It is necessary in spectroscopic observation to have as much light as can be gathered into a single point, and for this a large glass is essential. It follows from this that great telescopes have a mission to perform. While, on the one hand, they do not possess the almost miraculous gifts which imaginative persons would place to their credit, they do possess properties which render them much superior to smaller instruments and well worth all the expenditure which their construction has involved." W.

ELECTRIC CANAL-TOWAGE IN GERMANY.

The *Elektrotechnische Zeitschrift* conveys the information that the firm of Siemens & Halske is at present engaged in constructing an experimental electrical outfit for a trial of the method on a section of one of the German canals.

The plant consists of a power station from which current is supplied through an overhead conductor to electric locomotives, which run upon a narrow-gauge railway laid along the canal bank. The canal boats, in this case, will simply be towed—a number in each tow—by the engine.

In experiments on electric canal-haulage made in this country several years ago on the Erie Canal, it was proposed to run an overhead conductor along the canal line, and to equip the boats with electric motors, taking current for actuating their propellers from the line by the usual form of trolley. This, it will be observed, is subtantially different from the German plan above described. W.

INTERESTING MINERAL DISCOVERIES.

The following important notices of recent mineral discoveries were presented at the recent meeting of the American Association in Boston:

One of these is the discovery, near San Diego, Cal., of an enormous vein of lepidolite (lithia mica). This vein, where it has the best exposure, has a width of 60 feet. It is being utilized as a source of lithium. It is worked as an open quarry, and it is estimated that no less than 1,500,000 tons of mineral are available.

Another no less interesting item is the discovery of a new deposit of celestite—strontium sulphate—at Put-in-Bay, O. Large deposits of this mineral, which have been mined in this region for years, lately became exhausted, when by accident a large cavity was broken into while digging a well on Put-in-Bay Island. The walls of this cavity, which is described to be substantially a huge geode, were found to be lined with celestite. W.

SULPHURIC ACID AS A BY-PRODUCT.

The *Engineering and Mining Journal* is authority for the following interesting technical item:

"A new and interesting development in the chemical industry of the United States is the utilization of the sulphuretted hydrogen gas developed as a by-product in the refining of asphaltum at the California Asphaltum Company's Works at Ventura, Cal. The gas is burned to sulphurous anhydride in the usual well-known manner and the product of the combustion is conveyed to the lead chambers. Owing to the method of its production the gas is of a high degree of purity, and the acid produced is also of high grade. At present the output amounts to 10 tons per day, when the works are run at their full capacity.

"The Pacific Coast is beginning to have an important chemical industry. Sulphuric acid is made on a rather large scale at one other plant, while the manufacture of bluestone and boracic acid, carbonic acid, epsom salts, magnesia and numerous other products is now carried on. The State of California has great natural resources upon which to base an important chemical industry, and its geographical position gives it an advantage in supplying certain markets of the Pacific Slope, so it is probable that a more important and interesting chemical industry will grow up there when the transportation problem is settled." W.

UTILIZATION OF SOLAR HEAT FOR POWER.

Prof. L. G. Carpenter, Fort Collins, Col., presented at the late meeting of the American Association in Boston the results of some interesting observations, continued during ten years, of the amount of solar energy received on our Western plains.

These observations show an intensity of from 7 to 17 calories per square meter, from 8 A.M. on sunny days. This is equivalent to from ½ to 1¼ horsepower per square yard. It appears also to be as reliable as the wind, which is exclusively used as a source of power for small plants. W.

NEW METHOD OF TESTING THE EFFICIENCY OF STEAM-PIPE COVERINGS.

A new method of testing the efficiency of coverings for steam pipes was described by Prof. Charles L. Morton before Section D of the American Association, which should be capable of yielding more accurate results than those in common use.

By this method a section of the steam pipe is heated electrically by means of a coil of wire in oil within the pipe. The amount of energy necessary to keep the pipe at a definite temperature is measured. Since the energy thus supplied is just sufficient to maintain a constant temperature, it must therefore equal the energy lost by the pipe. Hence, from the electrical energy supplied, the author is enabled to calculate the heat lost from the outside of the pipe.

As there is considerable discrepancy between the reported tests of the efficiency of a number of these materials in common use, the suggestion of this new method, which promises to yield more accurate results, is worth the attention of steam users. W.

THE SAND BLAST FOR CLEANING MASONRY.

The value of the sand blast for cleaning old and discolored masonry walls appears to be still open to question, but as all the facts bearing on the use of this mechanical agent for the purpose will be useful to the architect and builder, the latest reported example of the kind is herewith recorded on the authority of the *Iron Age*, viz.:

"The sand blast has been applied to the work of cleaning the stone walls of Pardee Hall, Lafayette College. The interior of the building was destroyed by fire some time ago, and after the standing walls had been pronounced safe for rebuilding, this method of removing the smoke-stains and crumbled surface was selected. The compressor was one of the Ingersoll-Sergeant direct-acting type, having a 10 x 10 inch steam cylinder and a 10 x 14½ air cylinder.

Ward & Nash sand blast apparatus was used. From the air receiver the air was carried by a pipe to the third floor of the building and from thence by a hose to the portable sand blast apparatus. The velocity given to the sand was quite high, and the bombardment of the particles cut away the discolored surface in a very rapid and satisfactory manner. The pointing between the stones was cut away, but that had nearly all been cracked by the fire and would have had to be done over again in any case. The sandstone arches and facing around the windows were cut away very rapidly, and care had to be taken that the dressed edges were not spoiled."

A NEW PROCESS FOR CASE-HARDENING INGOTS.

The Demenge process of hardening steel ingots, which is in use at one of the principal steel works of France, consists in directly carburizing one of the faces of the ingot, at the time of casting, by lining one of the vertical sides of the mold with carburizing substances. The carburizing action is prevented from penetrating too deeply into the inside of the ingot by casting the vertical side opposite to the carburizing side. The carburization of the one face by this method is said to be quite uniform.

The case-hardened surface is rather rough; but all irregularity disappears in forging, which may be effected without special precaution and at a comparatively low temperature, by the press rather than the steam hammer. Ingots of ½ to 3 tons have been cast in this manner; and a 3-ton ingot, 16 inches thick, reduced by forging and rolling to one-fourth that thickness, was found to contain from 1·78 to 1·5 per cent. of carbon between its hard surface and a depth of $\frac{3}{16}$ inch; from 0·60 to 0·40 per cent. between 1 and 2 inches from the surface, and from 0·35 to 0·15 per cent. between $3\frac{9}{16}$ and 4 inches.

This method appears to be capable of accomplishing substantially the same results as those attained by the so-called "Harveyizing," but more simply.

W.

APPLICATION OF WIRELESS TELEGRAPHY TO NAVIGATION.

Mr. W. J. Clarke, an American electrician, has suggested a means of detecting the presence of a ship or an iceberg by wireless telegraphy. The apparatus which he proposes is so arranged that when two ships approach each other a large vibrating gong will ring in each, and the transmitter is so arranged that the signal would be operated at a distance of from one to ten miles. Mr. Clarke claims that if it were made compulsory that sea-going vessels should be so equipped with the necessary outfit, it could be carried out at a small cost.

W.

IMPROVEMENT IN THE ART OF SEPARATING METALS ELECTRICALLY.

Tomassi, an Italian expert, has proposed a mechanical improvement in the operation of the electrolytic bath used for the extraction, separation and refining of metals, which may prove to be of practical value. The aim of the inventor is to reduce the resistance in the electrolytic cell, and thereby reduce the cost. His electrolyzer consists of a rectangular tank in which are placed two anodes between which is placed a circular metallic disc mounted on a gun-metal spindle, and capable of being rotated. The disc is partly out and partly in the bath, and so comes in contact with the air and the electrolyte. The part of the disc outside the electrolyte comes in contact with two scrapers, one on each side, which scrape off the spongy deposit and depolarize the surface. The anodes are either in the form of plates, or in receptacles containing coarse powder. When the cathode has a sufficiently thick layer of metal it is taken to a bath of molten metal similar to that deposited, and the electrolytic deposit is melted in the bath, and then the cathode is taken back to the electrolyzer. Mr. Tommasi claims that polarization is entirely done away with, that the metal deposited is removed as the deposition proceeds, and that the density of the liquids in all parts is the same. W.

MANGANESE STEEL FOR BURGLAR-PROOF SAFES.

The discovery of manganese steel is due to Mr. R. A. Hadfield, the present head of the famous Hecla Works, in Sheffield, England.

The discovery of a metal of such extraordinary properties, combining as it does the highest tensile strength with absolutely unapproached elongation, started steel metallurgists all over the world experimenting to see if they could discover some steel or alloy having even higher physical properties. This search has resulted in the discovery of some valuable steels, notably those produced through the addition of molybdenum and vanadium, but nothing equalling manganese steel in the combined properties of hardness and toughness has been produced.

It was long ago proposed that manganese steel would make a good burglar-proof safe, but as the material was too hard to be machined, no way was devised to apply it for the purpose.

This difficulty, it is stated, has at length been overcome. Experiments with guncotton and dynamite on manganese steel plates are said to have demonstrated that the resistance of this metal to the action of explosives is unequalled by that of any metal at present known. W.

AN ALUMINUM HAND-CAR.

An aluminum railroad hand-car is being built by the St. Louis Aluminum Casting Company, and the makers propose its adoption by railroad companies to take the place of the ordinary muscle-taxing contrivance used by track workers. The new car will be constructed largely of an aluminum alloy of great strength and lightness, that is, the wheels, body, and walking beam will be made of this metal. The axles will be of steel tubing. Other improvements will consist of gearing of the bicycle pattern, admitting of adjustments for speed, of ball bearings, and of a hub brake, whereby brake power may be applied by simply pressing a button. The new car will weigh not more than 150 pounds, or only about a third as much as the ordinary hand-car, and one man can lift it off or on the track. It is believed that two men can easily run it from thirty to thirty-five miles an hour for a limited time. W.

ELECTRIC RIVETING MACHINE.

Before the Institution of Naval Architects of Great Britain, at one of its recent meetings, there was presented a description and an account of the performance of an electric riveting machine, which has been successfully applied to ship-building purposes. The machine is portable, and can be carried to any part of the yard. After thoroughly testing its capabilities, the inventor claims that it can be advantageously substituted for the two most advanced types of such machines now in use, namely, the hydraulic and pneumatic machines. The capacity of the electric machine is 120 rivets per hour, and it can close rivets up to 1⅝ inches in diameter. The machine described at the meeting above named is said to have been steadily at work for months, closing 1,200 rivets per day of ten hours, with the attendance of only three men and a boy.

W.

HIGH EXPLOSIVES AND SMOKELESS POWDERS.

Mr. Hudson Maxim, a well-known authority in the field of modern high explosives, presented some highly impressive data on the subject before the Chemical Section of the Franklin Institute, at one of its recent meetings. The gist of his discourse was the strong advocacy of much more destructive projectiles than are now used in warfare. This will appear in the following abstract:

He dealt with the history and development of smokeless powders, with particular reference to the well-known Maxim-Schœpphaus progressive burning smokeless powder for cannon, which is an American invention, and which has been adopted in the United States Army and Navy.

"While this powder possesses many characteristics of originality and value in its chemical composition," he said, "its distinguishing feature is its character of combustion. This is known as progressive burning. The grains of the powder are made somewhat larger than the usual cannon powder, and are multi-perforated—that is, pierced with a large number of small holes. This shape of grain enables the presentation of a smaller initial combustion area in the gun than do other forms of powder grains. The combustion starting with a small area confined to the perforations, becomes more rapid as the holes become larger, presenting an increase of burning area. It is a modified form of this same powder which is proposed for throwing high explosives from ordnance. The torpedo powder is made with a view to presenting the minimum of area of the initial flame with consequent minimum of initial pressure.

"The present 12-inch United States seacoast rifle weighs about 52 tons, and will throw a projectile, consisting of 963 pounds of steel and a bursting charge of only 37 pounds of black rifle powder. The pressure used in the gun is about 35,000 pounds to the square inch, and with the usual forms of powder grains this pressure falls off rapidly, and the average pressure in the gun is about 22,000 pounds. This causes a velocity of the projectile, under the best conditions, of about 2,250 feet per second.

"With a torpedo gun weighing the same as the present 12-inch gun, costing the same, and being of the same length and of the same outside dimensions for the rear half of its length, but having a caliber of 24 inches, a half ton of high explosives may be thrown at the same velocity as by the 37 pounds of black powder. The basis for the reasoning is as follows:

"With a pressure of only 12,000 pounds at the breech, and 10,000 at the muzzle in the torpedo gun, an average pressure would be had of 11,000 pounds to the square inch, just one-half the average pressure in the 12-inch gun; but in the torpedo gun the pressure is exerted for the same length of travel of shot over four times the area of base of projectile; consequently from the torpedo gun the projectile would be thrown with twice the muzzle average, and hence a projectile of twice the weight may be thrown without sacrifice of velocity. In other words, a projectile may be thrown weighing 1 ton, consisting of ½ ton of steel and ½ ton of high explosive, with the same velocity and accuracy as the present 12-inch shell is thrown.

"The character of high explosive that will be thrown will be wholly insensitive to the shock of acceleration in the gun of such explosives as picric acid or wet guncotton.

"By making a torpedo shell consisting of 1 ton of steel and filled with ½ ton of picric acid, the deck armor of any battleship in the world could be penetrated by one of these shells thrown from a seacoast battery, and explode inside the vessel, or the same would pierce the belt armor of a protected cruiser like the "New York," and explode inside. The velocity of even this shell would be upward of 2,000 feet per second.

"I propose simply to throw larger quantities than are now thrown, without subjecting the gun to any more shock. Naval and military authorities must give attention to the aërial torpedo. The first shock from a torpedo gun to throw the missile I have described will render obsolete every battleship in the world. Then needless sums of money will not be expended on armor protection which does not protect. The American fleet expended $2,000,000 worth of ammunition on Santiago hills, and the damage done was probably not more than 10 per cent. of that sum.

"The war taught nothing concerning the value of the torpedo boat. The great lesson taught is the superiority of the American gunners and fighters. War is occasionally a necessary contingency, and when it comes we want the best tools to fight with." W.

THE OLDEST KNOWN ROCK.

Among the numerous interesting papers presented at the recent meeting of the American Association for the Advancement of Science was one by Prof. N. H. Winchell, State Geologist of Minnesota, in which he described the so-called greenstones of that State, and advanced certain arguments in support of the view that these rocks were the oldest known rocks in the world. He considers them to be the bottom rocks of the geological series and the representative of the original crust of the earth formed from the molten mass by the earliest solidification.

The so-called Laurentian rocks of Canada have hitherto been considered by geologists to represent the oldest rocks, but Professor Winchell advances proofs to show that the greenstones of Minnesota are older. W.

CAUSE OF THE GLACIAL PERIOD.

Mr. Warren Upham, at the Boston meeting of the American Association, presented some important data on this subject. He stated that the results of recent investigations showed that the cause of the glacial climate was the considerable continental elevation which occurred in immediately antecedent time, and that the amount of this elevation was much greater than was supposed. He stated further that the elevation for the northern half of North America amounted to from 3,000 to 5,000 feet above the present level. W.

LEAD *vs.* ZINC PAINTS.

G. R. Henderson, of the Norfolk & Western Railroad, contributes to the *Railroad Gazette* a report of a series of exposure tests to determine the efficiency of lead and zinc paints. For the different materials he reaches the following results:

Tin.—The best results were obtained with first coat white lead and second coat white zinc. The second coating of zinc gave generally the best results, and the second coating of lead the worst.

Galvanized Iron.—The same remarks apply to galvanized iron that were given for tin.

Sheet Iron.—The mixture of one-third white zinc and two-thirds white lead, for both coats, gave the best results on this material, and in general the zinc paint gave better results than the lead paints.

Poplar.—The second coats of zinc showed up well on poplar, no matter whether the priming coats were white lead or white zinc, or mixed lead and zinc. The lead second coating showed up the worst on this material, but in each case where the second coat was of zinc, totally or partially, the paint was in a perfect condition.

White Pine.—The remarks made relating to poplar apply to white pine also.

Yellow Pine.—This material seems to be difficult to properly treat with paints; the best results were obtained with the first coat of lead, and the second coat of lead and zinc mixed. Where the first coat was of lead and zinc mixed, or entirely of zinc, the results were poor throughout, which seems to indicate that as a general thing the lead is better for priming on this material.

Conclusion.—The lead priming and zinc coating are generally good for tin, galvanized iron, poplar and white pine. Sheet iron showed up best with both coats of mixed paints. Yellow pine appeared best with the first coat of lead and the second coat of lead and zinc mixed. Comparing the materials which were painted, we find that generally poplar retains the paint better than white pine, and would, therefore, be preferred for siding on buildings, etc. Yellow pine seems to be the worst of all for this purpose. Black iron, as a whole, seems to retain the paint better than either tin or galvanized iron. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, May 17, 1899.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 17, 1899.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 102 members and visitors.

Additions to membership since last monthly report, 43.

The President gave a brief outline of the plans being made by the Board for the appropriate celebration of the seventy-fifth anniversary of the Institute. These comprise a series of special anniversary meetings by the several Sections, to follow each other on successive evenings; the celebration to be concluded by a special meeting of the Institute, at which addresses will be delivered by distinguished invited guests and members of the Institute. It is proposed that the ceremonies above-outlined should occupy one entire week during the month of October, and that they should take place in one of the buildings of the Exposition to be held in the autumn.

The Secretary, at the suggestion of the President, gave a brief account of the joint meeting of the Chemical and Mining and Metallurgical Sections and the Lehigh Valley Branch of the American Chemical Society at Bethlehem, Pa., which took place on Tuesday, May 16th. (For an account of this meeting see the proceedings of the Sections.)

Mr. N. Monroe Hopkins, Washington, D. C., described and illustrated "The Pneumatic System for Preventing the Bursting of Water Pipes by Freezing." This method, invented by the speaker, consists, in brief, in introducing along the line of pipe to be protected, at intervals of say every 10 feet, where the pipe is exposed to the danger of freezing, a series of small globular air-chambers, to provide sufficient space for the increased volume of the water in solidifying. To insure the continuous maintenance of the air in these chambers, an automatically operating inspirator is introduced in the main service pipe, which, whenever a faucet is opened, causes the introduction of a small quantity of air, which finds its way to the chambers, thus insuring that they shall always be kept supplied.

The subject was discussed by Messrs. J. C. Trautwine and Spencer Fullerton and Mr. Hopkins.

The invention was referred to the Committee on Science and the Arts for investigation and report.

Mr. Wm. McDevitt, Inspector of the Philadelphia Board of Fire Underwriters, gave an account of his investigation of the recent explosion, which occurred at the chemical works of Frank H. Fleer & Co., No. 2343-45 Callowhill Street, this city. The investigation disclosed that the cause of the explosion was the priming of the contents of a large tank containing some 70 gallons of benzole used as a solvent in the final operation of manufacturing artificial vanillin.

The subject was discussed by Dr. Goldschmidt, Mr. Fullerton and others.

Several views by Mr. W. N. Jennings, showing the progress being made on the Exposition buildings, were shown, and described by the President. Mr. Jennings also exhibited a remarkable lightning photograph taken by him.

Adjourned. WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, May 3, 1899.*]

PROF. EDGAR MARBURG in the chair.

The following reports were considered:

Plastic Rail-bond for Electric Railways.—Thomas A. Edison and Harold P. Brown, New York.

Acid-blast Method and Apparatus for Etching Metal Plates.—Louis Edward Levy, Philadelphia.

Improvement in Internally-fired Water-tube Boilers.—Robert D. Kinney, Philadelphia.

The foregoing reports were passed on first reading and laid over under the rules for final consideration at the next stated meeting.

The following reports were passed finally:

Chimneys for Incandescent Lamps.—Ernest M. White, Philadelphia. A protest against the Committee's report was filed by applicant. Considered by the Sub-Committee. The Sub-Committee decided to reaffirm its report, and recommended that the protest be dismissed. Approved.

Improvement in Pipe-joints.—Clinton A. Higbee, Philadelphia.

ABSTRACT.—The Higbee pipe-joint consists of a taper thread, the section of same being of the truncated V variety, but the ridge of the throat is truncated to a greater extent than the base, so that a space will be left on the ridge of both the male and the female thread when the joint is made. It is claimed that a flow of metal will take place when the thread is forced up, which will have the effect of filling the remaining space, producing a better joint than it is possible to obtain with the standard V-threaded pipe-joint.

The invention is the subject of letters-patent of the United States to Clinton A. Higbee, No. 597,000, January 11, 1898, to which reference is made for additional details.

The Sub-Committee charged with the investigation of the merits of this invention decided to institute comparative tests of this joint with the standard joint without the use of any paste, such as plumbers use for closing the minute leaks due to imperfections of the joint. As the result of three separate tests of this nature, the conclusion is reached: (1) That neither the Higbee joint nor the standard joint is likely to give satisfaction without the use of some paste; and (2) that there is no material difference between the Higbee and the standard pipe-joint. [*Sub-Committee.*—Hugo Bilgram, Chairman; L. L. Cheny, J. Logan Fitts.]

Contribution to the Physics of Thermo-Chemistry.—Gustave Westman, Jersey City, N. J.

The Sub-Committee finds that while the thesis is intelligible, it is improbable *a priori*; also, that the proof submitted is entirely inadequate. [*Sub-Committee.*—Jos. W. Richards, A. W. Goodspeed, Livingston Morgan, Hugo Bilgram, Geo. F. Stradling.]

Railway Tie.—Edward L. Brown, Calverton, Suffolk County, N. Y.

Abstract.—This invention is the subject of letters-patent of the United States to Edward L. Brown. (Allowed July 6, 1898.)

It consists of a metallic tie for railways, composed of two duplicate parts, which, when brought together, will form a complete tie and rail clamp.

Each of this pair of members consists of a horizontal or base flange, and a vertical flange. The latter is cut away where it engages the rail flange in such manner as to form a hook, which is designed to embrace the outer flange of one rail, while on the opposite end a portion of the metal is turned aside, leaving a similar hook to embrace the inside flange of the opposite rail. The combination of these parts in duplicate, forms what is claimed to be a widened support for the rail. When in position, embracing the rail as above described, the two members constituting the tie—which are duplicates of each other in reversed position—are bolted together or otherwise secured in place. The report finds the invention to be open to several serious objections. [*Sub-Committee.*—H. F. Colvin, Chairman; D. R. Mehaffy, Jacob J. McConnell.]

SECTIONS.

(*Abstract of Proceedings.*)

Chemical, Mining and Metallurgical Section.—*Joint Meeting* in conjunction with the Lehigh Valley Branch of the American Chemical Society at Bethlehem, Pa., held Tuesday, May 16th.

Forty-five members and friends attended the meeting. A special car for the accommodation of the party was provided by the Passenger Department of the Philadelphia & Reading Railway Company.

The visiting members were received in Bethlehem by Dr. Joseph W. Richards, President of the Chemical Section, and a representative of the Bethlehem Steel Company. The itinerary of the meeting embraced a visit to and inspection of the Government Ordnance Plant at the Bethlehem Steel Company and the various buildings of the Lehigh University. After this inspection the visitors enjoyed a luncheon furnished by the local committee and adjourned to the Lecture Room of the Chemical Department of the University, where the formal proceedings of the meeting were held. Dr. Joseph W. Richards, presided.

The following communications were presented:

"On the Use of Iron in the Purification of Water and Sewage." Dr. T. M. Drown.

"The Theodolite Goniometer and Gnomonic Crystal Projection." Dr. J. W. Richards.

"The Manufacture of Graphite in the Electric Furnace." (Exhibition of specimens.) Dr. William H. Wahl.

"Historical Sketch of the Liquefaction of Gases." Dr. H. F. Keller.

"A New Volumetric Method for Magnesia." Mr. R. K. Meade.

At the close of the meeting, Mr. James Christie, president of the Mining and Metallurgical Section, made a brief address, expressing on behalf of the visiting members their appreciation of the courtesies received at the hands of the Local Committee of the Lehigh Valley Branch of the American Chemical Society.

MECHANICAL AND ENGINEERING SECTION.—*Postponed Meeting*, Tuesday, May 18th, 8 P.M., Mr. Wilfred Lewis, president, in the chair. The subject for discussion was "Hydraulic Transmission, Valves and Packing," and was opened by Mr. Jefferies, of Camden, N. J.

PHYSICAL AND ASTRONOMICAL SECTION.—The inaugural meeting of this Section was held this evening in the Lecture Hall of the Institute in the presence of a large number of interested participants.

The President of the Institute opened the proceedings with a brief congratulatory address. The Secretary of the Institute gave a brief account of the events leading up to the formation of the Section, whereupon, on motion, Dr. E. A. Kennelly was chosen chairman *pro tem.* and Dr. Wahl, secretary *pro tem.*

The inaugural address was then delivered by Prof. Cleveland Abbe, of Washington, D. C., his theme being "The Relation of Physics and Astronomy to the Development of the Mechanic Arts." Also, addresses apropos to the occasion were made by Prof. T. C. Mendenhall, president of the Worcester Polytechnic Institute, Worcester, Mass.; Prof. A. S. Mackenzie, of Bryn Mawr College, Pa.; Dr. A. E. Kennelly, Prof. George F. Stradling, Central Manual Training School, Philadelphia; Professor Luigi D'Auria, Philadelphia, and others.

Profs. George A. Hoadley, E. A. Partridge and George F. Stradling were appointed a special committee to suggest nominations for permanent officers, and to take such other measures as might be found necessary to perfect the organization of the Section.

The meeting passed a unanimous vote of thanks to Professors Abbe and Mendenhall, the invited guests of the Section, for their valued contributions to the proceedings of the inaugural meeting.

(The communications above referred to will appear in the *Journal* in due course.) W.

ELECTRICAL SECTION.—*Stated Meeting*, Tuesday, May 23d, 8 P.M., Professor Hoadley, President, in the chair.

The proceedings embraced a lecture by Mr. James Hamblett, manager of the Telegraphic Time Service of the Western Union Telegraph Company, New York, on the subject of "Electrical Clocks, Historically Considered, with a Description of the most successful Applications of Electricity to Clocks and the Uniform Distribution of Time."

Mr. Hamblett illustrated his remarks by the exhibition of models and lantern slides.

Mr. J. D. Darling described and exhibited a new form of primary battery, known as the "Harrison Cell," for which special merits were claimed.

(The foregoing communication will appear in the *Journal.*) W.

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